MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. SUPPLEMENTARY NUMBER, 1898. No. 9

Enquiry for Letters of Gauss.

A letter has been received from Professor Stäckel, of Kiel University, asking that publicity may be given to the following request :—

The *Königliche Gesellschaft der Wissenschaften zu Göttingen* hopes shortly to complete the edition of the works of Carl Friedrich Gauss. The *Gesellschaft* therefore requests all those persons or Societies who are in possession of any manuscripts or information of interest concerning Gauss, kindly to communicate such material.

The Sidereal System Revised in 1898. By Maxwell Hall, M.A.

Up to the present time the solar orbit has been assumed to be circular, and both Γ and Λ have been taken equal to zero ; but it will be found that the theory is considerably improved by taking $\Lambda = -1$ as a first approximation.

Referring to the formulæ for computation, *Monthly Notices*, vol. lvii. pp. 360, 370, for $v^2 = \mathrm{F} r_0^2$, we now have

$$\rho_0 = \frac{2\mathrm{V}(au - b + \mathrm{H}\Pi\mathrm{V})}{c^2 + u^2 - \Pi^2\mathrm{V}^2 + \Lambda \,.\, \varpi^2\mathrm{V}^2 \,.\, \Pi^2 r_0^2}.$$

The last term in the denominator becomes of great importance among those stars whose computed parallaxes are large ; and the results of the last general computation clearly show that such a controlling term is required.

We shall now recompute all parallaxes and radial velocities on the supposition that $v^2=Fr_0^2$; but, when necessary, on the supposition that $v^2=Fr_0$, the circumstance being duly noted, as recommended in the last revision referred to above, p. 369.

We now require an expression for ρ_0, when $v^2=Fr_0$; and as the expression for ρ_0 when $v^2=Fr_0^2$, as given above, leads to unnecessary complications—such, for instance, as that in some cases the numerator and denominator of ρ_0 are both negative—we shall take a simpler form.

Thus

$$v^2=Fr_0,$$

and in the case of the Sun,

$$V^2=FR_0+\Lambda V^2,$$

or

$$F=\Pi V^2(1-\Lambda).$$

And as we have taken $\Pi=0{\cdot}02$, $V=5$, and $\Lambda=-1$, it follows that $F=1$; but we shall retain F in the equations, as it is not likely that 1 will be its final value.

Now, referring to the fundamental equations

$$v^2=V^2+(c^2+u^2)\rho_0^2-2V(au-b)\rho_0 ;$$

therefore

$$(c^2+u^2)\rho_0^2-2V(au-b)\rho_0=Fr_0-V^2,$$

or

$$(c^2+u^2)\rho_0-2V(au-b)=\varpi(Fr_0-V^2),$$

whence

$$\rho_0=\frac{2V(au-b)+\varpi(Fr_0-V^2)}{c^2+u^2}.$$

And, collecting our expressions as on p. 370, *Monthly Notices*, vol. lvii., we have

$$F=\Pi V^2(1-\Lambda)$$

$$v^2=Fr_0 ;$$

$$r_0=\sqrt{R_0^2+\rho_0^2+2HR_0\rho_0} ;$$

$$u=\frac{K+a\Pi V+\varpi\Gamma V}{H+\Pi\rho_0} ;$$

$$\Gamma=L\lambda+M\mu+N\nu ;$$

$$\rho_0=\frac{2V(au-b)+\varpi(Fr_0-V^2}{c^2+u^2} ;$$

$$\frac{d\rho}{dt}=-u\rho_0 ;$$

$$\varpi=\frac{1}{\rho_0}.$$

From the former list of stars we shall omit No. 2, α Argûs

(*Canopus*), whose proper motions are zero; but to that list we must add the following :—

Star	Mag.	R.A. 1850 h m s	P.M. in R.A. s	N.P.D. 1850 ° ′	P.M. in N.P.D. ″
α Eridani	0·5	1 32 7	+0·0080	148 0	+0·070
α Scorpii	1·1	16 20 13	− ·0022	116 6	+ ·028
β Centauri	1·2	13 53 17	− ·0100	149 39	+ ·050
α Crucis	1·3	12 18 18	− ·0060	152 16	+ ·040
α Piscis Aust.	1·3	22 49 21	+ ·0232	120 25	+ ·159
β Crucis	1·4	12 39 0	− ·0090	148 52	+ ·030
α Gruis	1·9	21 58 45	+ ·0110	137 41	+ ·150
β Hydri	2·7	0 17 47	+ ·7200	168 6	− ·320
δ Ursæ Maj.	3·4	12 7 59	+ ·0133	32 8	− ·004
η Aquilæ	4·1	19 44 50	− ·0017	89 23	+ ·003
β Comæ	4·4	13 4 52	− ·0605	61 22	− ·897
31 Aquilæ	5·3	19 17 49	+0·0487	78 22	−0·651

The above P.M.s are those of Dr. Auwers and those of Dr. Stone, as adopted by the *Nautical Almanac*. The following are the results of observation :—

Star.	″	Parallax, &c.
α Eridani		Gill.
α Scorpii	0·021	Finlay, *Monthly Notices*, vol. lviii. p. 172.
β Centauri	0·046	Gill. „ „ „
α Crucis		„
α Piscis Aust.	0·130	„ „ „ „
β Crucis		„
α Gruis	0·015	„ „ „ „
β Hydri		„
δ Ursæ Maj.	0·09	Bruno Peter, *Nature*, vol. lvii. p. 546.
η Aquilæ	$\frac{dp}{dt} = -1$.	Belopolsky, „ „ p. 353.
β Comæ	0·11	Bruno Peter, „ „ p. 546.
31 Aquilæ	0·06	„ „ „ „

It will be convenient to arrange the results of the recomputation in two Tables, the first containing satisfactory, or fairly satisfactory, results, from stellar orbits more or less circular; and the second containing failures probably due to elliptic, or highly elliptic, orbits.

TABLE I.

No.	Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	Computed. ϖ	Computed. $\frac{d\rho}{dt}$
		"		"	
1	α Canis Maj. (*Sirius*)	0·27	0?	0·17	0
3	α Boötis (*Arcturus*)	0·07	− 9	0·31	− 9
4	α Centauri	0·72	...	0·65	− 3
5	α Aurigæ (*Capella*)	0·07	+ 7	0·05	+ 6
6	β Orionis (*Rigel*)	0·03	+ 4	0·04	+ 11
7	α Lyræ (*Vega*)	0·12	− 9	0·14	− 11
*	α Eridani (*Achernar*)	...	...	0·01	− 1
8	α Canis Min. (*Procyon*)	0·23	+ 2	0·11	+ 5
9	α Orionis	0·02	+ 6	0·04	+ 10
10	α Aquilæ (*Altair*)	0·20	− 8	0·26	− 10
11	α Tauri (*Aldebaran*)	0·10	+ 11	0·04	+ 9
12*	α Virginis (*Spica*)	...	− 4	0·00	− 2
*	α Scorpii (*Antares*)	0·02	...	0·00	− 4
*	β Centauri	0·05	...	0·00	+ 1
14	α Leonis (*Regulus*)	0·09	+ 1	0·02	+ 6
*	α Crucis	...	...	0·00	+ 3
	α Piscis Aust. (*Fomalhaut*)	0·13	...	0·06	− 6
*	β Crucis	...	...	0·00	+ 2
15	α Cygni	0·01	− 7	0·02	− 8
16	α Gemin. (*Castor*)	...	− 6†	0·49	− 4
18	ε Orionis	...	+ 6	0·04	+ 11
20*	ε Ursæ Maj.	0·08	− 1?	0·02	− 4
21	α Persei	0·09	− 6	0·03	− 1
22	β Tauri	0·06	+ 2†	0·04	+ 8
23	α Ursæ Maj.	0·05	− 9	0·20	− 8
24*	η Ursæ Maj.	...	− 6	0·01	− 5
	α Gruis	0·02	...	0·01	− 2
25*	β Aurigæ	0·06	− 6	0·08	− 4
26	α Andromedæ	0·06	− 4?	0·03	− 1
27	α Ursæ Min. (*Polaris*)	0·05	− 6	0·03	− 9
28	γ Andromedæ	...	− 3	0·00	0
29	α Arietis	0·08	− 4	0·03	+ 3
31	γ Cassiopeiæ	0·01	− 4	0·02	− 4
32	θ Andromedæ	0·07	+ 2	0·03	+ 1

* $v^2 = Fr_0$. † Potsdam.

No.	Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	Computed. ϖ	Computed. $\frac{d\rho}{dt}$
		″		″	
34*	γ Leonis	...	− 9	0·13	− 3
35	β Leonis	0·03	− 3	0·03	+ 1
36*	ζ Ursæ Maj.	...	− 7†	0·02	− 4
40	γ Cygni	0·10	− 3	0·02	− 9
41	β Cassiopeiæ	0·16	0	0·06	− 4
42	α Cassiopeiæ	0·04	− 3	0·02	− 4
43	β Persei (*Algol*)	0·05	0	0·01	+ 2
44*	β Ursæ Maj.	0·08	0	0·02	− 1
45	γ Ursæ Maj.	0·10	− 5†	0·04	− 3
47*	ε Pegasi	0·08	+ 2†	0·05	+ 2
48	α Pegasi	0·08	0†	0·03	+ 2
49*	ε Boötis	...	− 4	0·00	3
50	α Cephei	0·06	−14	0·03	− 9
51	β Pegasi	...	+ 1	0·05	− 2
	β Hydri	...	...	0·22	+ 7
52*	β Libræ	...	− 2	0·01	− 4
53*	α Serpentis	...	+ 5	0·03	+ 1
54	ε Cygni	0·13	...	0·09	− 7
55*	δ Leonis	...	− 3	0·04	− 4
56*	β Herculis	...	− 8	0·01	− 8
60	δ Herculis	0·08	...	0·01	−11
*	δ Ursæ Maj.	0·09	...	0·03	− 3
62	η Cassiopeiæ	0·31	...	0·11	− 3
64	10 Ursæ Maj.	0·20	...	0·05	+ 5
65	70 (p) Ophiuchi	0·22	...	0·17	−10
66	θ Cassiopeiæ	0·23	...	0·04	+ 2
67	e Eridani	0·14	...	0·56	+12
68	o^2 Eridani	0·19	...	0·57	+ 1
	β Comæ	0·11	...	0·38	+ 3
69	δ Ursæ Min.	0·03	...	0·03	− 9
70	δ Equulei	0·04	...	0·06	+ 3
71	σ Draconis	0·25	...	0·38	− 3
72	ν^2 Draconis	0·28	...	0·11	−13
73	ν^1 Draconis	0·32	...	0·11	−11
75	61 Cygni	0·43	...	0·67	− 7
76	μ Cassiopeæ	0·18	...	0·32	− 2
77	ε Indi	0·22	...	0·45	+ 6

* $v^2 = Fr_0$. † Potsdam.

No.	Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	Computed. ϖ	Computed. $\frac{d\rho}{dt}$
		"		"	
78	Cephei 51 (Hev.)	0·03	...	0·04	− 8
79	3077 Bradley	0·18	...	0·21	− 4
80	85 Pegasi	0·06	...	0·12	− 1
81	20 Leonis Min.	0·06	...	0·09	−10
83	1618 Groombridge	0·25	...	0·69	+ 5
84	Σ 1516	0·15	...	0·17	−10
87	Σ 2398	0·35	...	0·96	+ 2
88	34 Grcombridge	0·31	...	0·30	− 1

TABLE II.

No.	Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	Computed. ϖ	Computed. $\frac{d\rho}{dt}$
		"		"	
13	β Gemin. (*Pollux*)	0·06	− 7?	...	...
17	γ Orionis	...	+ 2	0·04	+10
19	ζ Orionis	...	+ 3	0·04	+10
30	γ Geminorum	...	− 4	0·10	+10
33	δ Orionis	...	0	0·4	+11
37	β Ursæ Min.	0·02	+ 3	0·04	−10
38	α Ophiuchi	...	0?	0·02	− 5
39*	α Coronæ	...	+ 7	0·02	− 4
46	γ Draconis	0·07	− 2	0·04	−12
57	ι Ursæ Maj.	0·13	...	0·84	− 6
58	θ Ursæ Maj.	0·05	...	1·54	− 7
59	α Herculis	0·05	...	...	...
61	π Herculis	0·11	...	1·25	−12
63	η Herculis	0·40	...	...	...
	η Aquilæ	...	− 1	0·04	− 9
74	ξ Toucani	0·06	...	1·72	+ 9
	31 Aquilæ	0·06	...	0·46	−10
82	1830 Groombridge	0·13	...	2·67	− 6
85	21 185 Lalande	0·46	...	1·50	− 7
86	9352 Lacaille	0·28	...	2·30	− 5
89	21 258 Lalande	0·23	...	2·32	+ 4
90	17 415 Oelt. Argel.	0·20	...	1·40	+ 2
91	11 677 Oelt. Argel.	0·18	...	1·25	− 9

By comparing Tables I. and II. we arrive at the following results :—

1. The present revision gives about 20 per cent. of failure,

* $v^2 = \mathrm{F} r_0$.

while the last revision gave about 40 per cent.; and in consequence the introduction of Λ has proved a marked success.

2. But the percentage of failure is not constant throughout the list; the stars are arranged according to their magnitudes, and while the percentage is very small among the brighter stars, it increases as the stars diminish in brightness; and among the very faint stars (which were, of course, picked out for observation of parallax on account of their very large proper motions), there are many failures.

No. of Stars Computed.	No. of Failures.	Percentage of Failure.
10	0	0
20	1	5
30	3	10
40	5	12
50	8	16
60	9	15
70	13	19
80	15	19
90	17	19
100	21	21

3. Now when it is remembered that a large number of the brighter stars give correct results in *both* parallax and radial velocity, there can be no doubt that as far as our problem is concerned the brighter stars should be observed for parallax and radial velocity instead of the fainter stars having abnormally large proper motions; and as the numerical work is now becoming very heavy, it seems advisable to omit at present the further computation of stars of the latter class.

4. In the last revision of 1896 the results from $v^2=\mathrm{F}r_0^2$ were slightly preferable to those from $v^2=\mathrm{F}r_0$; but it appears from a number of the brighter southern stars at great distances from the centre that we are now obliged to give the preference to $v^2=\mathrm{F}r_0$.

From certain investigations I made many years ago on the number and the distribution of the stars, it appears that they really do diminish in number with the distance from the Sun, which was assumed to be not far from the centre; and I believe it was this effect which once led to the idea of the gradual extinction of light in its passage through space.

It therefore appears advisable to use the equation for ρ_0 resulting from $v^2=\mathrm{F}r_0$ in our further investigations, as given above on p. 474.

This change in the law of force necessitates the recomputation of the coefficients of the correction $\Delta\lambda$, $\Delta\mathrm{L}$, &c., to be applied to the adopted values λ, L, &c., as given on p. 371 of the last revision. But the calculation of the coefficients by such formulæ is difficult and liable to error. It will, perhaps, be better to proceed in the manner suggested by Lieutenant Stratford for the

correction of the elements of the orbit of Halley's Comet. (Appendices to various *Nautical Almanacs*, p. 196.)

Thus to find $\frac{d\varpi}{dV}$ for any star, increase V by unity, and recompute; this will give the change in ϖ corresponding to a change of +1 in V, or approximately $\frac{d\varpi}{dV}$.

Similarly, $\frac{d\varpi}{d\Lambda}$ and $\frac{d\varpi}{d\Pi}$ may be found.

But instead of finding $\frac{d\varpi}{d\lambda}$, &c., we must increase the apex 1° in R.A., the N.P.D. being unchanged; and by computing the new λ and μ, and the new ϖ, we get $\frac{d\varpi}{da}$. Similarly by increasing the apex 1° in N.P.D., the R.A. remaining unchanged, and by computing the new λ, μ, and r, and the new ϖ, we get $\frac{d\varpi}{d\beta}$.

And similarly we must treat the position of the Sun as seen from the Centre, and get $\frac{d\varpi}{dR}$ and $\frac{d\varpi}{d\Delta}$.

Of course, the same computations will apply to a system of corrections based upon radial velocity as well as upon parallax. And then from the two systems we get equations similar to

$$\mathfrak{A} \cdot \Delta\lambda + \mathfrak{B} \cdot \Delta\mu + \&c. + \Delta\varpi = 0$$
$$\mathfrak{A} \cdot \Delta\lambda + \mathfrak{B} \cdot \Delta\mu + \&c. + \Delta\frac{d\rho}{dt} = 0,$$

where $\Delta\lambda$, $\Delta\mu$, &c., are the corrections to be applied to the assumed values of λ, μ, &c., and where $\Delta\varpi$ is the observed minus the computed parallax, and where $\Delta\frac{d\rho}{dt}$ is the observed minus the computed radial velocity.

Jamaica:
1898 *June* 2.

Observations of Jupiter in 1898. By W. F. Denning.

During the period from 1898 March to July I observed *Jupiter* on 51 nights in my 10-inch Browning-With reflector. I usually employed one of Steinheil's "monocentric oculars," consisting of three cemented lenses and giving a power of 312. Occasionally I used the single lens of a Huygenian magnifying 252, and more rarely one of Browning's achromatic eye-pieces with a power of 488. But, ordinarily, the power of 312 possessed a marked advantage over the others.

I obtained about 280 estimated transits of the various markings on the planet, with a view to finding the individual

velocities of the currents in which they were situated. The results for each object observed are given in a tabular form at the end of this paper. About eight different currents were manifested, of which the following is a summary :—

Approx. Latitude.	Number of Objects seen.	Description of Objects.	Period of Rotation. h m s
°			
+39	1	Dark oval spot on NN. temp. belt	9 55 47·8
+33	1	Dark oval spot in bright zone	9 55 52·5
+15	3	Dark oval spots	9 55 26·3
Region of Equator	23	Dark and white spots	9 50 23·6
−21	1	Great red spot	9 55 41·8
−30	4	Dark and white spots on S. temp. belt	9 55 20·5
−35	2	White spots in zone S. of preceding	9 55 14·0
−40	2	Dark spots	9 55 8·6

The latitudes are by estimation. It is possible that the first two objects may represent one current only, the difference in their rotation periods being less than 5 seconds. It is noteworthy that these objects in the N. hemisphere were the only ones observed which were moving more slowly than the great red spot. The spot in Lat. +39°, which was really a swell or thickening in the NN. temp. belt, could not be followed after May 23 ; it had lengthened out, and its material appeared to be in process of distribution along the belt. The oval spot in Lat. +33° survived until early in July, when, however, it was seen with difficulty.

With reference to the equatorial spots, they were so numerous, subject to so many variations in form and distinctness, and influenced by such different, and apparently irregular, velocities, that it was often hard to identify the same objects with certainty. The 23 markings included in the table are chiefly selected as being the most conspicuous of their class, and affording satisfactory means of identification. It will be observed, on comparing the rotation periods for the individual spots in this current, that the motion was far from being equable, and that it exhibited large discordances in different longitudes. The extremes were those of a dark spot (No. 3) in λ 29°·2 on June 11, rotation period $9^h\ 50^m\ 33^s{\cdot}2$, and of a similar spot (No. 19) in λ 300°·5 on May 8, rotation period $9^h\ 50^m\ 16^s{\cdot}9$. The numerous other objects circulating along this region presented a variety of periods between the extremes mentioned. This difference in relative velocities induced some complications of a puzzling character, for it enabled certain spots to overtake and pass others moving at slower rates. Thus No. 11 in the table of equatorial spots was east of No. 10 in April, but apparently passed it in May, and was afterwards placed on its western side. No. 23 may be regarded as a special object, inasmuch as it was situated on the N. equatorial belt, but it moved at about the same rate as that shown by a mean of all the other equatorial spots in the table which were placed on the N. side of the S. equatorial belt.

The mean rotation period of $9^h\ 50^m\ 23^s{\cdot}6$ is $6^s{\cdot}4$ shorter than the adopted period ($9^h\ 50^m\ 30^s$) on which system I. in the ephemerides is based. It proves that the velocity of the equatorial current of *Jupiter* received considerable acceleration between the spring of 1897 and that of 1898. From 8 spots observed at the former season Mr. A. Stanley Williams deduced a mean rotation period of $9^h\ 50^m\ 34^s{\cdot}6$ (*Monthly Notices*, 1897 November, p. 13), which is exactly 11 seconds greater than the mean of my own observations in 1898. It would appear, therefore, that the equatorial current, after slackening from $9^h\ 50^m$ in 1879 to $9^h\ 50^m\ 34^s{\cdot}6$ in 1897, has now markedly increased its rate. This has varied as follows, according to previous observations here :—

	h	m	s
1880	9	50	5·8
1881	9	50	8·8
1882	9	50	11·4
1885	9	50	14·3
1886	9	50	22·8
1895	9	50	34·3
1898	9	50	23·6

As to the great red spot, it has recently been exceedingly faint. The *f* side was the plainest, but the complete oval outline of this marking was distinctly seen on but one occasion this year, when the image was beautifully defined and very steady. On March 22, and on a few subsequent occasions when fairly good glimpses were obtained, I remarked that the red spot did not appear to be symmetrically placed within the dip or bay in the S. side of the S. equatorial belt. The W. side or *p* shoulder of the bay was, however, flatter than the E. side, and moreover there was a very bright streak curving round the N. *p* side of the spot, and extending from that region to the planet's W. limb. This would naturally induce the impression that the spot was a little E. of the centre ; I believe, however, even though the circumstances favoured a mistaken view, that the spot decidedly leaned to the *f* side, and the Rev. T. E. R. Phillips, of Yeovil, noticed the same thing on several occasions.

This configuration is not new, for it was noticed here on various nights during the oppositions of 1895 and 1897, but particular attention was not paid to it. It is a point which can only be settled by micrometric measurements, but the present extremely feeble aspect of this marking must render these very difficult. The motion of the spot appears to have further slackened, but only in a slight degree. In July the middle of the spot was in $\lambda\,28°$, so that it was seen at mid-transit 46 minutes after the passage of the zero meridian of System II. in Mr. Crommelin's ephemerides (*Monthly Notices*, 1898 April). The values referred to ($\lambda\,28° = 46^m$) represent the cumulative effect of the difference between the rate of motion of the red spot and the period of $9^h\ 55^m\ 40^s{\cdot}63$, upon which System II. is

based, since the summer of 1894, when the position of the red spot coincided with that of the zero meridian. In point of fact, the mean rotation period of the spot during the four years (nearly) from 1894 August 10 to 1898 July 30 (3,504 rotations) was $9^h\ 55^m\ 41^s{\cdot}4$, or $0^s{\cdot}78$ greater than the period adopted in System II.

There were visible three dark, elongated spots,* just exterior to the N. equatorial belt, and situated on a very delicate, narrow belt, in about Lat. $+15°$. These rotated at an average rate of $15\frac{1}{2}$ seconds less than that of the red spot at the same period. Relatively to the position of the latter these markings would, therefore, complete a revolution round *Jupiter* in 954 days, while the equatorial spots have recently occupied only $46\frac{1}{2}$ days. S. of the *f* ends of the three objects alluded to, and touching the N. side of the N. equatorial belt, there were bright spots which maintained their positions, and were at times strikingly brilliant. The *p* ends of the dark spots sometimes appeared bent abruptly to S., and in actual contact with the equatorial belt, but when definition was good the junction could not be confirmed, and the impression of its existence seemed due to the fact that the bright spots at the *f* ends intensified the division in that part, while the more dusky space between the *p* ends and the belt brought about the apparent coalescence of the objects, especially on a night when definition was indifferent.

The white and dark spots in Lat. $-30°$ seem to have changed their rate of motion very little, if at all, from that observed in previous years, when the rotation period was about $9^h\ 55^m\ 18^s$. Further south the spots are influenced by a much swifter current, but they are subject to such variations, and often nearly obliterated by inferior definition, that it is difficult to secure a sufficient number of really accurate observations to enable their exact periods to be ascertained. Quite possibly the two pairs of spots, in Lat. $-35°$ and $-40°$ respectively, may be situated in the same current, with a mean period of about $9^h\ 55^m\ 11^s$.

In determining the rotation periods in the following table I have compared two or three of the earliest with a similar number of the latest transits of the same object when the observations were sufficiently numerous for that purpose. In cases where a spot was observed for position on very few occasions, the first and last transits were utilised, and, in deriving the results, the more doubtful observations were rejected. The longitudes of the spots exterior to the equatorial belts were computed with reference to the zero meridian of System II., and the longitudes of the equatorial spots were based on System I. of Mr. Crommelin's ephemerides in *Monthly Notices*, 1897 November and 1898 January.

* Several additional markings of similar character and position were seen early in the opposition by Herr Fauth at Landstuhl, and at a later period by Mr. A. Stanley Williams at Brighton. The three objects observed at Bristol appear, however, to have been the most conspicuous and durable, and to have attracted the notice of a large number of observers.

Rotation Periods of Markings Outside the Equatorial Region of Jupiter, 1898.

No.	Description of Object.	Approximate Latitude.	Mean Longitude.	Mean Date.	Whole Period of Observation.		Length of Interval.	Rot. tions.	Period of Rotation.	No
					h m	h m	d h m		h m s	
1	Dark oval spot on belt	+39°	285°·8	May 5	April 17, 9 18	May 23, 9 14	35 23 56	101	9 55 47·8	1
2	Dark oval spot in bright zone . . .	+33	280·9	May 20	April 7, 10 39	July 3, 8 22	86 21 43	210	9 55 52 5	2
3	Dark oval spot	+15	110·8	May 13	Mar. 23, 9 25	July 4, 8 40	102 23 15	249	9 55 27·7	3
4	„	+15	238·4	June 1	April 17, 8 32	July 17, 8 1	90 23 29	220	9 55 26·3	4
5	„	+15	287·3	May 15	Mar. 14, 12 5	July 17, 9 10	124 21 5	302	9 55 24·8	5
6	Great red spot	−21	26·8	May 26	Mar. 22, 10 43	July 30, 8 29	129 21 28	314	9 55 41 8	6
7	White spot on S. temp. belt . . .	−30	1·8	May 11	April 15, 10 12	June 7, 8 20	52 22 8	128	9 55 21·7	7
8	„ „ „ . . .	−30	11·7	June 1	May 14, 9 18	June 19, 8 40	35 23 21	87	9 55 21·6	8
9	„ „ „ . . .	−30	127·9	May 13	April 4, 9 53	June 22, 9 3	78 23 10	191	9 55 19·4	9
10	Dark mass on S. temp. belt	−30	137·9	June 8	May 15, 8 46	July 2, 7 51	47 23 5	116	9 55 19 5	10
11	White spot in zone S. of S. temp. belt	−35	157·7	April 24	April 4, 10 30	May 15, 8 36	40 22 6	99	9 55 14·4	11
12	„ „ „	−35	297 0	May 25	April 22, 9 25	June 28, 8 43	66 23 18	154	9 55 13·7	12
13	Dark ellipse	−40	126·5	May 19	April 16, 9 57	June 22, 8 47	66 22 50	154	9 55 9·5	13
14	Dark spot	−40	291·9	May 29	April 22, 9 25	July 5, 9 13	73 23 48	179	9 55 7·7	14

Notes.

1. This object was seen by Dr. A. A. Nijland, of Utrecht, on April 5, in λ 289° Lat. + 38° (*Ast. Nach.* 3488). It was not definitely recorded after May 23, having dispersed itself along a dusky belt.

2. Ten observations were obtained. The spot gradually became faint, and could not be seen at the middle of July. The Rev. T. E. R. Phillips obtained the place of this object on March 21 as λ 265°·5, and March 28 λ 267°·7. Dr. Nijland saw it on April 5 and found it in λ 272°, Lat. + 31°. This object, and the preceding, are shown on a planisphere of *Jupiter* (opposition of 1898) by Signor J. Comas Solá, in *Ast. Nach.* 3,519. He, however, depicts the markings as having a more strikingly beaded or knotted aspect than was observed here.

3. Nine observations. Spot apparently first seen by Brenner on January 20 in λ 144°·5 (*Ast. Nach.* 3476).

4 and 5. These spots were recorded by Fauth as early as 1897 Nov. 25 in λ 305° and 360° (*Ast. Nach.* 3488). I obtained seven observations of No. 4 and seventeen of No. 5. The former was much the smaller of the pair, and could not be seen at all on nights of bad definition.

6. This object was extremely faint, and its elliptical contour usually quite indeterminate. It would often entirely escape notice but for the depression in the S. equatorial belt which guides the eye to its position. The southern boundary of the spot was fringed with dark material, apparently by coalescence with the N. side of the S. temperate dusky belt.

7. Six observations. This marking was in conjunction with the red spot on about March 23.

8. Only three observations were obtained. Conjunction with the red spot occurred on May 10, and it was very bright at about this time with a luminous trail running some distance to S.E.

9 and 10. These showed a period 2ˢ less than Nos. 7 and 8, but the difference may have arisen either from errors of observation or from a real inconsistency in the rate of motion of the various objects.

11, 12, 13, and 14. Eight observations were obtained of No. 14, but very few of the others. Reliable transits could only be secured when the definition was very good. Early in July No. 14 appeared to have lost its definite character and to have distended itself along a dusky belt on its southern borders. No. 13 appears to have been first seen by the Rev. T. E. R. Phillips at Yeovil on March 23, and for several months it remained a remarkably definite object.

Rotation Periods of Equatorial Spots on Jupiter, 1898.

No.	Spot.	Mean Longitude of Spot.	Mean Date.	Whole Period of Observation.		Length of Interval.			Rotations.	Period of Rotation.			No.
				h m	h m	d	h	m		h	m	s	
1	D	0°·1	July 9	June 19, 7 50	July 30, 8 11	41	0	21	100	9	50	28·9	1
2	W	18·5	June 11	May 18, 8 39	July 5, 8 9	47	23	30	117	9	50	26·1	2
3	D	29·2	June 11	May 18, 8 49	July 5, 8 31	47	23	45	117	9	50	33·2	3
4	D	62·2	May 13	Mar. 22, 10 15	July 5, 9 2	104	22	47	256	9	50	19·5	4
5	W	73·0	May 24	April 7, 10 14	July 10, 7 30	93	21	16	229	9	50	19·6	5
6	D	87·3	May 27	April 7, 10 31	July 17, 7 33	100	21	2	246	9	50	24·7	6
7	D	120·4	May 27	April 7, 11 26	July 17, 8 17	100	20	51	246	9	50	24·4	7
8	W	143·0	May 30	April 12, 10 4	July 17, 8 58	95	22	54	234	9	50	26·1	8
9	D	154·1	May 23	April 1, 8 36	July 15, 8 8	104	23	32	256	9	50	28·0	9
10	W	208·8	April 28	April 15, 8 39	May 12, 10 8	27	1	29	66	9	50	27·5	10
11	D	207·3	May 29	April 15, 8 54	July 13, 8 6	88	23	12	217	9	50	17·9	11
12	W	212·8	June 3	April 24, 9 26	July 13, 8 22	79	22	56	195	9	50	22·9	12
13	D	221·1	June 12	May 12, 10 34	July 13, 8 43	61	22	9	151	9	50	26·6	13
14	D	236·9	May 25	April 24, 10 0	June 25, 8 0	61	22	0	151	9	50	25·2	14
15	W	260·6	May 15	April 4, 8 41	June 25, 8 26	81	23	45	200	9	50	19·5	15
16	D	271·5	May 8	Mar. 14, 11 6	July 2, 8 5	109	20	59	268	9	50	20·7	16
17	W	280·0	June 3	May 6, 8 40	July 2, 8 26	56	23	46	139	9	50	20·2	17
18	W	295·9	June 15	May 15, 9 38	July 16, 7 33	61	22	55	151	9	50	20·6	18
19	D	300·5	May 8	Mar. 14, 12 5	July 2, 8 41	109	20	36	268	9	50	16·9	19
20	D	313·7	June 26	June 7, 9 11	July 16, 8 9	38	22	58	95	9	50	24·2	20
21	W	339·5	May 23	April 16, 8 9	June 30, 8 46	75	0	37	183	9	50	19·6	21
22	D	354·9	May 14	April 16, 8 19	June 12, 8 20	57	0	1	139	9	50	24·6	22
23	W	123·9	June 15	May 14, 9 7	July 17, 8 30	63	23	23	156	9	50	26·8	23

In the second column "D" means Dark spot, "W" White spot.

Notes.

1. Five observations. The spot was very dark and distinct, and coincided in position (and very nearly in rate of motion) with that of the zero meridian of system I.

2. Five observations. Spot fairly conspicuous, and moving at nearly same rate as preceding.

3. Five observations. This object apparently gave the longest period of all the equatorial spots, but it was only followed during forty-eight days, which is hardly long enough for exact results.

4. Nine observations. A well-observed object and one of the most definite of its class.

5. Fourteen observations. In June and July this spot became remarkably brilliant, and was certainly more conspicuous than any other marking of similar character near the equator.

6. Eleven observations. Spot well defined, and its identity on different nights satisfactorily assured.

7. Very few observations were made, but the period derived is in good agreement with Nos. 6 and 8.

8 and 9. Seven and eleven observations. These spots, like Nos. 4 and 5, were of very pronounced type and observed sufficiently often to render identification quite certain. They moved slowly as compared with many other of the markings in the same latitude.

10. Only three observations were made, but there is little question that the same object was seen on each occasion.

11. Six observations. This object moved much faster than the foregoing, and apparently passed over it in May, but there is some doubt as to its identity.

12, 13, and 14. Few observations were obtained, though the objects were fairly conspicuous.

15 and 16. Nine and eleven observations. A well-defined pair of spots, of which an adequate number of transits were secured. They moved at nearly the same rate as the equally well observed pair of spots Nos. 4 and 5, but much swifter than Nos. 8 and 9.

17 and 18. Three and five observations. This pair apparently rotated with a velocity uniform with the preceding. They were, however, insufficiently observed, though there seems no reason to question their identification.

19. Six observations. This spot moved very rapidly, and at an irregular rate. Its velocity appears to have been greatest between May 5 and June 7.

20. Five observations. This object apparently moved much slower than the dark spot preceding it or the white spot which followed it.

21 and 22. Four observations were obtained of these objects. The former was very brilliant at times, and occasionally showed itself in the division between the N. and S. sides of the great S. equatorial belt. Its variations of aspect were remarkable and occurred at very short intervals.

23. This spot was recorded on only a few occasions, but it occupied a special position, breaking into the N. equatorial belt. Its rate of motion, being generally consistent with that of the other spots situated on the N. side of the great S. belt, sufficiently proves that the same current prevailed over a considerable zone in the equatorial region of the planet.

The Great Red Spot on Jupiter. By W. F. Denning.

In *Nature* for 1898 August 4 I made some general comments on the associations and rate of motion of this remarkably durable object. Having been further examining the evidence bearing on the early history of the spot, it may be interesting to refer to some of the descriptions of this object in and since 1869, and then to give a table of the varying rotation period it has exhibited during 29 years. I have grouped the observations into periods of about three years, and have selected what appeared to be the most accurate. Though the times of transit had, in several cases, to be estimated from sketches they are believed to be fairly good, as they were carefully checked by other observations made at nearly the same period. Everything lends countenance to the view that the large brick-red spot detected by Russell, Pritchett, and Dennett in 1878 July, and by Tempel, Niesten, and others in the following month, was identical with the object described and figured by Gledhill in 1869 November 14 to 1870 March 29, and on 1871 December 1; by Mayer in 1870 January 5; by Knobel, Birmingham, Pratt, Terby, and Browning in the early months of 1872; by Lord Rosse and Dr. Copeland, 1872 December 31 to 1873 April 10; by Russell and Bredichin in the summer of 1876; and by other observers at various times. True the spot was not continuously visible (or, if so, must have curiously eluded notice), and before 1878 it appears to have been much involved in the brighter material floating in the upper regions of the Jovian atmosphere. But the latitude of the spot, the general size and form of it, the rate of its rotation period, its colour, and the peculiar shouldering of the S.S.* equatorial belt, S. of its preceding and following ends, are all very significant features, and leave no reason to doubt that Gledhill's ellipse, first seen in 1869 November 14, was really the forerunner of the red spot, then perhaps in an incipient stage, and certainly not nearly so well developed as when Lord Rosse and Dr. Copeland rediscovered and followed it, on the last day of 1872 and during the early months of 1873, with the 6-foot reflector at Parsonstown.

1869 November 14 to 1870 March 29. The great southern ellipse was a fine object, and easily seen every clear night. It lay between the S.S. equatorial belt and the S. temperate belt. Its eastern end was the darkest part of it. It was followed up to 1870 March 29, and its transits or approximate positions relatively to the central meridian were noted on twenty-two nights. J. Gledhill ($9\frac{1}{3}$-inch refractor), *Astronomical Register*, vol. viii. p. 81, &c.

1870 January 5. "A great elliptical ring observed in the

* This term is adopted for brevity to distinguish the dark belt forming the southern side of the southern equatorial double belt.

planet's S. hemisphere and just S. of the equatorial belt. Its major axis to the minor axis is in its present projection as 1 to 1·51." It was about central at $8^h = 13^h\ 30^m$ G.M.T. A. M. Mayer (6-inch refractor), *Franklin Institute Journal*, 1870 February 7, and *Astronomical Register*, vol. viii. p. 169.

1871 December 1, $11^h\ 30^m$. S. of the S.S. equatorial belt, and near the W. edge of the disc, was a very large dark spot, and to the E. of this object lay the ellipse. Within it was seen a short, slightly curved dark line. A pretty dark band was in contact with the upper edge of the ellipse. A rough measure gave 15″ as the length of the longer diameter of this curious object. J. Gledhill ($9\frac{1}{2}$-inch refractor), *Astronomical Register*, vol. x. p. 11.

1872 January 5, 15^h; January 6, 10^h; and on February 2 and April 11, 16, and 28. A notable slanting streak was observed and drawn in the S. hemisphere; and following it was a well-defined elongated spot or preceding side of a belt lying S. of the great S. equatorial belt. E. B. Knobel ($8\frac{1}{2}$-inch reflector), *English Mechanic*, 1872 September 13.

*1872 January 6, 10^h to $10^h\ 45^m$. On the eastern part of the S. white zone, outlying the dark equatorial belt and just coming into view, was a dusky marking, its western end having an oval outline. H. Pratt ($8\frac{1}{2}$-inch reflector), *Astronomical Register*, vol. x. p. 43.

*1872 January 11 and 13. A striking feature is the belt-like streak which descends from the S., crossing the truncated end of the S.S. equatorial belt at a sharp angle, and reaching down to the S. equatorial belt. A large oval spot follows the slant belt. J. Birmingham ($4\frac{1}{2}$-inch refractor), *Astronomical Register*, vol. x. p. 42.

1872 February 2, 7^h. The sloping band is well seen, and to the east there is a dark and very broad cloud-like mass. J. Gledhill ($9\frac{1}{3}$-inch refractor), *Astronomical Register*, vol. x. p. 68.

1872 February 2, $7^h\ 46^m$. The S. temperate belt dips to N., and following it in about same latitude there is a renewal of the belt in an intensified form. F. Terby ($3\frac{1}{2}$-inch refractor), *Bulletin de l'Acad. R. de Belgique*, vol. xxxiv. Nos. 9 and 10, 1872.

1872 March 17. The slant streak now appears to extend to the dark region about the S. pole. In the angular space between it and the S.S. equatorial belt, and reaching

* Two well-executed sketches of the appearances referred to by Birmingham and Pratt may be seen in *Astronomical Register*, 1872 February. The oval spot presents a very striking resemblance to the red spot of later years. It is to be regretted that Mr. Birmingham did not give the exact times of his observations on Jan. 11, 13, or March 17.

quite across, is a large black spot, and under the spot a bright gap seems cut out of the S.S. equatorial belt. J. Birmingham ($4\frac{1}{2}$-inch refractor), *Astronomical Register*, vol. x. p. 94.

*1872 May 5, 9^h 15^m. A coloured sketch of *Jupiter* at this time shows a white slanting band as about central, while following it is a large dark mass. J. Browning (12-inch reflector), *Monthly Notices*, vol. xxxii. p. 322.

1872 December 31 to 1873 April 10. Of all the features presented to our view during the opposition of 1873 probably the most remarkable was the great break in the southern side of the equatorial belt in long. 260°. . . . Following and filling up this break was a brick-red area that was seen most fully on February 6. . . . The red region may extend over some 30° of longitude, reaching from 250° to 280°; its following end was well seen on March 22. The red area was also seen on 1872 December 31, 1873 January 17 and 22, February 8, March 7, and April 10. Lord Rosse and Dr. Copeland (6-foot reflector), *Monthly Notices*, vol. xxxiv. p. 243.

1873 April 20 and May 11. Two sketches of *Jupiter* exhibit the dip in the S.S. equatorial belt and a dusky mark coming into view on the E. limb. E. B. Knobel ($8\frac{1}{2}$-inch reflector). *Monthly Notices*, vol. xxxiii. p. 476.

1876 June 2, 0^h 35^m G.M.T. The red spot was frequently seen in 1876, and many drawings of it were made at the Sydney Observatory. The distance from the S. pole of *Jupiter* to the dark belt on the N. border of the spot was $15''{\cdot}54$, and in 1880 the same space was measured as $15''{\cdot}94$, so no change occurred in the latitude. In 1876 the *p* end of the spot was round and the *f* end pointed, while in 1873, according to Rosse and Copeland's drawings, the *p* end was pointed and the *f* end round. A sketch of the planet on June 2 at Sydney represents the red spot just entered on east limb. The spot was first seen separated from the belts on 1878 July 8; it was then a difficult object to see, but its form and dimensions were similar to that observed in 1876, and the observer was

* The objects depicted by Browning are identical with those alluded to by Knobel, Birmingham, Pratt, Gledhill, and Terby in the previous winter months.

The slanting streak seems to have almost monopolised the attention of observers at this period, while the dark oval mass following it was not much regarded, though really of far greater significance, for it appears to have been undoubtedly the forerunner of the red spot.

The curved dark line seen in the interior of the ellipse by Mr. Gledhill on 1871 December 1 seems to have been preparatory to the filling up of that object with dark material. When it was observed by Knobel on 1872 January 5 and 6 and February 2, by Pratt on January 6, by Birmingham on January 11 and 13, and by Gledhill on February 2 it simply appeared as a dark elliptical mass.

not long in recognising it as an old friend that he had frequently seen. H. C. Russell ($11\frac{1}{2}$-inch refractor), *Proceedings of the Royal Society of New South Wales*, vol. xiv. pp. 63–75.

1876 June 20, $7^h\ 30^m$ G.M.T. The spot was drawn just passing off the west limb. It was a dark and definite object with distinctly oval outline. T. Bredichin, *Annales de l'Observatoire de Moscou*, vol. iii. 1877.

Great Red Spot on Jupiter. Rotation Period 1869 *Nov.* 14 *to* 1898 *July* 30.

Observers.	Dates of the Observations.	Interval.	Rotations.	Corrected Rotation Period.	Daily Rate.
	h m	d h m		h m s	°
J. Gledhill	1869 Nov. 14 10 50				
		1,209 1 10	2,923	9 55 34·4	870·42
Lord Rosse and Dr. Copeland	1873 Mar. 7 12 0				
		1,182 13 20	2,859	9 55 34·1	870·43
H. C. Russell	1876 June 2 1 20				
		852 11 9	2,061	9 55 33·4	870·45
L. Trouvelot	1878 Oct. 2 12 29				
		725 22 29	1,755	9 55 34·2	870·43
F. C. Dennett, W. F. Denning	* 1880 Sept. 27 10 58				
		1,164 1 43	2,814	9 55 37·3	870·35
W. F. Denning	1883 Dec. 5 12 41				
		1,108 6 44	2,679	9 55 39·6	870·30
,, ,,	1886 Dec. 17 19 25				
		1,074 8 29	2,597	9 55 40·2	870·28
,, ,,	1889 Nov. 26 3 54				
		1,174 2 21	2,838	9 55 40·7	870·27
,, ,,	1893 Feb. 12 6 15				
		1,093 0 34	2,642	9 55 41·0	870·26
,, ,,	1896 Feb. 10 6 49				
		901 1 40	2,178	9 55 41·7	870·24
,, ,,	1898 July 30 8 29				
J. Gledhill	1869 Nov. 14 10 50				
		10,484 21 39	25,346	9 55 37·8	870·34
W. F. Denning.	1898 July 30 8 29				

By selecting other observations in lieu of those utilised in the preceding table, it will be found that the periods deduced from them will be in very fair agreement. Thus, comparing an observation by A. M. Mayer on 1870 January 5, $13^h\ 30^m$, with one by T. Bredichin on 1876 June 20, 6^h, I find the mean period $9^h\ 55^m\ 34^s{\cdot}2$ (5,700 rotations). Bredichin's observation, when combined with one by F. C. Dennett, 1878 September 28, $9^h\ 24^m$, gives a mean period of $9^h\ 55^m\ 33^s{\cdot}8$. Other observations sufficiently prove that previously to the year 1878 the rate of motion of the spot was slightly increasing, but that a retardation set in afterwards. This retardation was very marked in the years 1880, 1881, 1882, and 1883. During this period the annual increase in the rotation period of the object amounted to one second, while during the 14 years from 1884 to the present time

* This is a mean of the estimated times of the same transit taken by two observers. In subsequent years the observations are those made at Bristol.

the average yearly increase has been only 0·2 second or one-fifth of a second.

A few of the objects offering a suggestive resemblance to the red spot, which were figured by observers in 1872 and other years, are certainly not to be identified with the latter. For instance, the dark oval marking drawn by Terby * on 1872 January 3 on the S.S. equatorial belt, and by Corder † in a similar position on 1872 March 13 and April 18, relate to one and the same formation, but it preceded the red spot by as nearly as possible three hours. Elliptical markings occasionally appear in the planet's S. hemisphere which are of more temporary character than, and probably somewhat different in nature to, the red spot. In 1885 a conspicuous red marking, known as the 'new red spot,' was seen on the S.S. equatorial belt, but it did not long remain visible.

In conclusion I give the annual rates of rotation exhibited by the spot. This table is only intended to show the general changes that have occurred; doubtless there have been well-marked minor variations causing a longitudinal oscillation of the object at comparatively short intervals. These, however, could only be satisfactorily traced by comparing a large number of very accurately observed transits. Mr. Marth had contemplated investigating the movement of the spot since 1879, but I fear the work was not completed at the time of his lamented decease.

Rotation Period in Successive Years of the Great Red Spot on Jupiter.

	h m s		Comparisons with other Observers.		
	9 55 +				
1869	34·5				
1870	34·4				
1871	34·4				
1872	34·3				
1873	34·3	30s·6	1872 Dec. 31–1873 April 10, Rosse and Copeland		
1874	34·2				
1875	34·0				
1876	33·7				
1877	33·4				
1878	33·7				
1879	34·1	34·0	1879, G. W. Hough	34·1	1878–80, Marth
		33·9	1879 July–Dec., H. Pratt	34·4	1879-80, Schmidt
1880	35·2	35·1	1880, H. Sternberg	35·3	1879–81, Schmidt.
		35·4	1880, G. W. Hough		

* *Bulletin de l'Académie Royale de Belgique*, vol. xxxiv. Nos. 9 and 10, 1872.
† *Observatory*, 1882 January.

h m 9 55 + s		Comparisons with other Observers.	
1881	36·3	36·1 1881, H. Sternberg 36·4 1881, G. W. Hough	
1882	37·3	37·3 1882, H. Sternberg	
1883	38·2	38·1 1883, H. Sternberg 38·4 1883, G. W. Hough	
1884	39·0	39·2 1884, H. Sternberg 38·5 1883 Sept. 12–1834 June 11, G. W. Hough	1883–5 38″·9, Marth
1885	39·6	40·1 1885, H. Sternberg 40·4 1884 Sept. 25–1885 June 29, G. W. Hough	
1886	39·9	40·1 1886, H. Sternberg 40·7 1886, C. A. Young 39·9 1886, G. W. Hough	
1887	40·1	40·6 1887, H. Sternberg 40·5 1887, A. S. Williams	
1888	40·2		
1889	40·4		
1890	40·5	39·8 1890 July–December, G. W. Hough	
1891	40·6	40·7 1890 December 8–1892 January, G. W. Hough	
1892	40·8		
1893	40·9		
1894	41·0	40·9 1893 December 20–1895 January 24, G. W. Hough	
1895	41·1		
1896	41·3	41·4 1896, G. W. Hough	
1897	41·6	42·4 1897 March–May, A. S. Williams	
1898	41·9	42·4 1898 March–June, T. E. R. Phillips	

Bristol: 1898 *September* 15.

Observations of Jupiter and Jupiter's Satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the Opposition 1897–8. By Joseph Gledhill.

This paper comprises the following subdivisions :—

1. A description of the principal features seen on the disc of *Jupiter*.
2. Transits of red spot, dark spots, &c.
3. Measures of the position of the principal dark belts and spots.
4. Measures of the bright zones, dark spots, &c.
5. Observations of phenomena of *Jupiter's* satellites.

6. Notes on certain phenomena presented by *Jupiter's* satellites and their shadows during transit across the disc.

The observations were made with the 9-inch Cooke Equatorial Refractor (object glass, one of the new triple lenses by Messrs. T. Cooke and Sons, York) and a Simms parallel-wire micrometer. The negative eyepieces used were of powers 150 and 240 ; the measures were made with a power of 200. The planet was examined on every fine night from October 1897 to July 1898. On no occasion could a power higher than 240 be used. Some idea of the exceptionally bad observing conditions which prevailed during the opposition may be formed from the following statement: *a*, number of nights continuously clear throughout ; *b*, good observing nights ; *c*, fair ; *d*, bad ; *e*, sunless days.

	a	*b*	*c*	*d*	*e*
1897 October	5	1	2	5	13
November	2	0	0	6	20
December	2	0	4	12	8
1898 January	0	0	1	4	15
February	4	0	4	9	8
March	6	4	4	10	4
April	2	0	3	4	6
May	0	4	2	6	6
June	3	0	5	6	4

A Description of the Principal Belts, &c., seen on the Disc of Jupiter during the Opposition, 1897–8. For terminology of Bands, &c., see *Measures of the Position, &c.*

Band o (*the S.S. Temperate Band*).

This somewhat faint grey band near the S. pole was not easily seen in all longitudes. Even when definition was good it was sometimes a difficult feature. In certain longitudes, however, it was easily seen as a broad grey band, as the following notes will show. The longitudes are from Mr. Crommelin's Ephemeris system II.

1898 March 8, $11\frac{1}{2}^h$, $\lambda=106°$ (*i.e.* longitude of the central meridian of the apparent disc) ; faint and narrow. March 10, 11^h, $\lambda=28°$; the band is faint ; it is about as far S. of 1 as 1 is S. of 2. March 14, 11^h, $\lambda=240°$; well seen. March 19, 11^h, $\lambda=300°$; well seen. March 20, 9^h, $\lambda=20°$; well seen ; $10\frac{1}{2}^h$, $\lambda=90°$; faint. March 21, 11^h, $\lambda=243°$; not seen, yet 1 is a very easy feature. March 23, 9^h, $\lambda=111°$; well seen ; 10^h to 11^h, $\lambda=148°$ 184° ; not seen as a belt distinctly separated from the polar shading to the S. March 30, 11^h, $\lambda=157°$; not seen. April 5, 11^h and 12^h, $\lambda=339°$ and 16° ; well seen. May 6, 10^h,

$\lambda=283°$; easy, a distinct band all the way across the disc. At 9^h, $\lambda=247°$; a wider and darker portion of the band had reached the central meridian ; and a large dark spot on it was central about $10^h\ 24^m$, $\lambda=298°$. May 11, 7^h, well seen ; $\lambda=206°$. May 16, $8\frac{1}{2}^h$, well seen, $\lambda=291°$. May 18, $10^h\ 10^m$, the dark spot was central, $\lambda=292°$. At this time the band was as broad as 1, and more distant from 1 than 1 from 2. May 28, $8^h\ 20^m$, $\lambda=288°$; faint. June 28, $8\frac{1}{2}^h$ to 9^h, $\lambda=269°$ to $287°$; well seen, a little darker and broader than 1.

So that it appears to have been well seen in longitudes of central meridian 16° to 28°, 200° to 250°, and 270° to 340° ; and very faint in about 90° to 110°, and 140° to 180°.

Band 1 (*the S. Temperate Band*).

This band was always visible, sometimes quite narrow and faint, at others quite a prominent feature. Its general appearance was that of a strap-like, grey band ; but in some longitudes its S. edge was a sinuous line.

1897 October 21, 6 A.M., well seen all across the disc. 1898 February 16, $12\frac{1}{2}^h$, $\lambda=15°$; faint. February 18, 11^h, $\lambda=261°$; faint. February 21, 10^h to 12^h, $\lambda=316°$ to $28°$; very faint. February 22, 12^h, $\lambda=180°$, faint ; and on the 24th at 11^h, $\lambda=83°$, and the 27th at 12^h, $\lambda=211°$. March 2, 10^h, $\lambda=230°$; well seen. March 3, 12^h, $\lambda=92°$; faint ; and on the 6th at 10^h, $\lambda=110°$; but at 12^h it began to widen a little to the east of the central meridian, say when $\lambda=184°$. March 7, 12^h, $\lambda=334°$; well seen ; also at 11^h on the 10th, $\lambda=29°$. March 12, 10^h faint ; $\lambda=293°$. March 14, 10^h, $\lambda=234°$; well seen, it ranks next to 2, 3, and 4 in prominence. March 19, 11^h, $\lambda=303°$; well seen. March 20, 9^h, $\lambda=21°$; well seen ; so also on the 21st at 10^h, $\lambda=207°$. Passing over a good many similar observations the following may be given as times when the band was very faint : February 21, as above ; also May 12, 7^h and 8^h, $\lambda=356°$ and 33°, very faint and narrow ; so also on May 18, 9^h, $\lambda=250°$. The sinuous appearance of the S. edge was well seen on May 14, at 8^h, $\lambda=315°$ and the band was faint. On April 12, 7^h to 10^h, $\lambda=167°$ to $276°$; the band was well seen, and at 8^h, $\lambda=203°$, it was nearly as wide as zone *b*. The sudden widening of the band was seen on March 6 as above, and also on May 3, May 6, May 8, May 12, and June 27.

Band 2 (*the S. Component of the S. Equatorial Belt*).

There has probably been very little change in the appearance of this band since the last opposition. The two shoulders are still very marked features in it, and so are its disappearance between the shoulders and its sudden change of depth of tone in a certain longitude. The following notes give all the most noticeable observations :—

It was seen narrower than 3 on February 8, 13^h, $\lambda=269^\circ$, and not so dark; also on February 16, 12^h, March 6, 10^h, March 30, 11^h; as dark and broad as 3 on March 20, 11^h, March 23, 9^h, May 15, 8^h, May 16, 7^h, May 18, $8\frac{1}{2}^h$. On March 7, 12^h, it appeared broken up into dark portions, or had dark forms on it. Its S. edge was irregular in outline on March 20, 11^h, and on March 23, at $8\frac{1}{2}^h$. The darkest and most striking portion of the band is at the *f* shoulder; and at this place too a kind of tuft or wisp was often seen projecting into the bright zone to the south. The other noteworthy feature is its sudden change in depth of tone and in width; when this point was seen near the W. limb (*i.e.* passing off the disc) it was known that the *p* and *f* shoulders would soon be seen at the E. limb. When the red spot was on the central meridian the faint and narrower portion of 2 extended quite to the *p* limb.

Band 3 (*the N. Component of the S. Equatorial Belt*).

Of all the dark bands seen on the disc of *Jupiter* during this opposition this has been in many respects the most interesting. Its S. edge has often presented a fairly uniform and undisturbed outline; it has been dark and broad in all longitudes—indeed, the darkest and broadest band on the disc—and the dark oblong spots on, or detached portions of, this band, the bright gaps between them, the apparent shift of some portions to a more northern latitude, and the draggling down (to N.) of cloudy matter or form into the central zone, have formed very interesting objects of observation. A few notes selected from a large number will show the general character of these phenomena:—

1897 October 21, 6 A.M., the band was broken up into detached dark portions. 1898 February 8, some of the dark forms project into the central zone; so also on February 16 and February 18. On February 21, 13^h, three dark elongated portions of the band lay under and in contact with the N. edge of the band. February 22, 11^h to 12^h, a gap or break was seen in 3, followed by a dark spot on it; and just to the east of the spot the band became darker all the way to the *f* limb of the planet. Bright gaps and dark spots, or detached short portions of the band, were also seen on February 23, 11^h; February 24, 11^h and $12\frac{1}{2}^h$; February 27, 12^h; March 2, 13^h, and many other nights. Sometimes, as on March 6, 10^h, the whole band was a series of six or more dark portions with bright spaces between them. These detached oblong portions were occasionally seen slightly inclined to the general direction of the band, as on March 10 at 11^h. There was a dark spot or protuberance just under (to N. of) the *p* shoulder on June 12, $8\frac{1}{2}^h$, and it projected into the central zone. This was often seen. A similar form was seen just under, or a trifle behind (to E.), the *f* shoulder, *e.g.* May 14, $7\frac{1}{2}^h$. On May 16, $8\frac{1}{2}^h$, the whole band consisted of three detached portions.

Bands 2 and 3 lay very close together, leaving but a very narrow bright zone between them, except when 2 became suddenly pale, grey, and narrower, *i.e.* a few hours before the red spot reached the central meridian.

Band 4 (*the N. Equatorial Belt*).

This prominent band (double during the opposition of 1896–7, but single during that of 1897–8) was quite as much broken up as band 3. Its south edge was in most longitudes ill defined. The following notes will give a good idea of the phenomena presented by this band during a rotation of the planet :—

1897 October 21, 6 A.M., as dark and broad as 3 and more broken up, the S. edge being a series of projecting forms, the N. edge a smooth line. 1898 February 18, 11^h, as dark as 2 or 3. February 24, 11^h, seems double. February 27, 12^h, a fairly uniform band. March 6, 10^h, not nearly so broad as 3 ; so also at 12^h. March 12, 10^h, nearly as dark and broad as 3. March 20, 9^h, as wide and dark as 3, and broken up. March 21, 13^h, very broad and dark. March 24, 9^h, as on March 20 ; same on March 30, 11^h. April 4, $9\frac{1}{2}^h$, narrow and dark. April 12, 7^h, as on February 18. May 4, 10^h, narrow and dark ; N. edge sharp ; S. edge indefinite. May 12, 8^h, narrow ; 11^h, not so dark as 3. It was dark and broad on May 15, $7\frac{1}{2}^h$; May 16, 7^h ; and May 27, 10^h ; narrow on June 22, $10\frac{1}{2}^h$.

Band 5 (*the N. Temperate Band*).

This band was nearly always faint, sometimes very faint, and perhaps altogether absent in some longitudes. Its width was not the same in all longitudes. To give its appearance as 'faint,' 'very faint,' 'much fainter than 1' on the thirty to forty nights on which it was examined would serve no useful purpose here. 1898 February 22, 11^h, an elongated dark spot was seen on band 5, a faint narrow band ; this faint band was seen again at 10^h, March 6. March 10, 11^h, the band is very faint, and is a little more distant from 4 than 1 is from 2 ; it is a mere line. March 23, 9^h, distance of 5 from 4 equals that of 5 from 6 ; at $9\frac{1}{2}$, distance of 5 from 6 is less than that of 4 to 5. At 10^h and 11^h band 5 was broad and well seen. June 27, 8^h, in the same longitude as the *f* end of the dark spot *a*, but a little to the N., appeared a similar narrow spot, probably forming part of band 5, which was seen as a narrow band to the east, but not to the west, of the spot. This was seen again on June 27, about 8^h, and on a later date. With good definition it would, no doubt, have been seen every time spot *a* came near the central meridian.

Band 6 (*the N.N. Temperate Band*).

The following notes contain a summary of all that was seen of this faint band : 1898 March 10, 11^h, it was darker and broader

than 1, and much darker and broader than 5. March 14, 10^h, darker than 5 : its darkest part was on the central meridian, about $10^h\ 45^m$. The band was very faint on 19 March at 11^h, and on the 20th at 9^h ; but at $10\frac{1}{2}^h$ on the latter day it was broad and dark, as on 10 March. It was faint or very faint on March 30, 11^h, April 4, $9\frac{1}{2}^h$, May 3, 11^h, and May 12, 8^h ; on May 6, 10^h, it was seen as a mere grey line. At $8\frac{1}{4}^h$ on June 22 the p end of a darker portion of the band was on the central meridian ; this darker eastern portion was as broad and dark as 1.

The Bright Zones b (S. Tropical) and d (N. Tropical).

These two zones were always the brightest portions of the disc, and b was perhaps always brighter than d on the more than forty nights of observation.

The Central Zone (Equatorial Zone).

This zone was always of a warm yellow or ruddy colour, and was often mottled, but it was found impossible to see clearly the forms of the markings. In its northern part, near the dark band 4, a faint discontinuous band was occasionally seen : *e.g.* on 1898 March 20, at $10\frac{1}{2}^h$, two portions of this band were seen ; also at 13^h on February 21, and at $7\frac{1}{2}^h$ on May 14.

The Polar Regions.

During the moments of best definition on good nights the shading in these regions could be seen to consist of fine lines or bands for a considerable part of the distance between 0 and 6 and the poles. The principal facts that appear from the observations are : (1) the region a was probably brighter than e in all longitudes ; (2) the shading in e was always (at any rate after May 3) much less distinct than that in a : this difference was quite marked on several occasions. When the lines in a were well seen all was hazy and indistinct in e. (3) The region a was occasionally bluish, while that of e was yellowish.

The following are the observations :—1898 February 20, March 10, 12^h, March 31, 9^h to 10^h, May 3, $8\frac{1}{2}^h$, May 4, 7^h, May 8, 9^h, May 16, 7^h, May 18, 7^h, the shading in a was brighter than that in e. On March 12, 10^h, March 20, 9^h, March 21, 9^h, a was much brighter than e. On May 3, $8\frac{1}{2}^h$, the S. edge of e was dark or formed by a narrow dark band. On May 4, 10^h, the shading in a was seen broken up into fine grey bands, while that in e was quite indistinct. May 11, 7^h, e had a dark S. edge. May 12, 8^h, a distinct, e indistinct or cloudy ; but at $10\frac{1}{2}^h$ both were equally definite and bright. On May 6 at 8^h a was for once darker than e. It is probable that the low altitude of the planet would account for some differences of colour, such as, for example, that contained in the observation on May 6 at $9\frac{1}{2}^h$,

"the S. polar region is bright and white, while all to the N. of band 4 is yellowish."

From the foregoing notes it will be seen that the salient features visible on the disc of Jupiter during this opposition were as follows: the double dark band 2, 3 just S. of the equator; the single dark band 4 just N. of the equator, the coloured central zone, and the grey band 1. On fine nights, and almost in all longitudes, the faint bands 0, 5, and 6 could be seen; and in certain longitudes portions of a narrow band were seen in the northern part of the central zone. Of course, too, on fine nights the irregularities—gaps, protuberances, &c.—on bands 2, 3, and 4, in certain longitudes, were also very striking features. Lastly, three dark grey elongated spots were easy objects on good nights. Of bright circular spots few were seen, owing partly, no doubt, to the low altitude of the planet and the marked absence of nights of really fine definition. A few small bright circular spots were seen between bands 2 and 3, on the S. edge of band 0, and between bands 4 and 5.

Transits of the Red Spot, the Shoulders, Dark Spots, &c.

The Red Spot.

This object was difficult throughout the opposition. It was distinctly seen on but one or two occasions. The *f* end was often glimpsed. No trace of warm colour was ever seen within its outline. It will be obvious, therefore, that no great accuracy can be claimed for the times of its transit over the central meridian of the apparent disc.

1898.	h m	○	1898.	h m	○
Apr. 5	12 13	24	June 10	6 48	24
8	9 42	23	12	8 25	24
May 4	11 10	25	14	10 3	23
12	7 46	24	17	7 37	26
14	9 24	24	24	8 25	25
28	11 0	25	July 11	7 30	24
31	8 30	25	13	9 10	24

The p Shoulder.

This is not a very definite point: it is the point where the band 2 begins to bend down to band 3.

1898.	h m	○	1898.	h m	○
Apr. 5	11 46	7	May 31	8 0	7
8	9 14	6	June 9	10 25	6
10	10 56	9	12	8 0	9
May 4	10 40	7	14	9 35	6
12	7 20	8	17	7 7	7
14	8 56	7			

The f Shoulder.

1898.	h m	°	1898.	h m	°
Feb. 21	12 20	40	Apr. 8	10 5	37
23	13 55	39	10	11 46	39
Mar. 3	10 33	40	May 4	11 35	37
10	11 15	38	12	8 12	40
12	12 55	39	14	9 50	39
14	14 31	38	31	8 58	42
17	12 3	40	June 10	7 15	41
19	13 40	39	12	8 55	42
20	9 34	41	14	10 30	40
22	11 10	40	17	8 5	42
25	8 24	39	22	7 15	43
Apr. 5	12 35	37	24	8 55	43

Dark Spot a.

This was seen on Feb. 22 for the first time and under very bad atmospheric conditions ; it was not nearly so dark as band 4, close to the N. edge of which it lay ; it was on a very fine band. This fine band was again seen on March 6 at 10^h. On March 8 the spot was seen to be just out of contact with band 4. It was seen to be broadest and darkest at its western, *i.e.* preceding, end on March 10 at 13^h.

1898.	h m	°	1898.	h m	°
Feb. 22	10 40	130	May 12	10 10	111
Mar. 2	17 14	132	15	7 42	112
6	10 35	132	31	10 46	107
8	12 10	130	June 5	9 52	105
10	13 49	131	10	9 0	105
12	15 27	131	15	8 10	105
15	12 57	132	17	9 45	103
18	10 25	131	22	9 0	106
20	12 2	131	27	8 10	107
23	9 35	133	July 9	7 50	96
25	10 58	132	11	9 25	93
30	10 17	131	16	8 35	93

Dark Spot b.

This was a small faint spot, not in contact with dark band 4, just to N. of it, and about 1″ in length.

1898.	h m	°	1898.	h m	°
Mar. 14	10 55	268	May 6	9 0	247
21	11 38	266	11	8 9	248
24	9 5	265	18	8 50	244
May 3	11 33	249			

Dark Spot c.

This was a long grey spot just to the N. of dark band 4; the length, estimated, on Feb. 23 was about 3″; length to width, about 3 to 1. Its length, measured on March 31, was 4″·7 (reduced to mean distance).

1898.	h m	°	1898.	h m	°
Feb. 23	11 43	319	May 4	8 44	297
Mar. 2	12 25	317	6	10 12	291
7	11 32	317	11	9 15	288
12	10 34	314	16	8 28	290
14	12 9	312	18	10 0	286
17	9 39	313	28	8 20	288
19	11 17	313	June 9	8 15	287
21	12 52	311	14	7 17	283
24	10 24	313	28	8 43	277
31	10 57	306	July 10	8 35	273
Apr. 8	7 30	304	15	7 38	267
12	10 47	304			

Dark Spots on or close to N. Edge of Band 3.

1898.	h m	°	1898.	h m	°
Feb. 21	13 30	83	June 10	9 35	126
22	11 40	167	10	10 18	152
Mar. 2	15 57	86	14	9 35	6
7	12 0	334	15	8 35	120
10	13 42	127	17	9 45	103
12	14 10	85	17	8 47	68

Bright Gaps in Band 3.

1898.	h m	°	1898.	h m	°
May 6	8 5	214	May 11	8 25	257
8	9 40	212	18	8 40	238
11	7 0	206	18	10 35	308

Measures of the Position of the Principal Belts and Spots.

The bands (or belts) and zones will be readily identified with the aid of the terminology used by the *British Astronomical Association*, viz. the S.S. Temperate band (*o*), the S. Temperate zone, the S. Temperate band (*1*), the S. Tropical zone (*b*), the S. Equatorial belt (*2*, *3*), the Equatorial zone (*c*), the N. Equatorial belt (*4*), the N. Tropical zone (*d*), the N. Temperate band (*5*), the N. Temperate zone, the N.N. Temperate band (*6*), the

N.N. Temperate zone, the S. Polar Region (*a*), the N. Polar Region (*e*).

The position of a feature of the disc was determined by measures from both limbs (N. and S.), the web through the spot, &c., being made parallel to the belts. The value of one revolution of the micrometer screw is 13″·84, and one division of the divided head is 0″·138.

As an illustration of the kind of accordance in the measures on a good night the following extract from the note-book is given :—

1898 March 31, 41″·6, 42″·2, 42″·8, 41″·9, 41″·9, 41″·9, 41″·8, 42″·8, 42″·2, 42″·3, 42″·4, 41″·9. Mean, 42″·14 ; mean difference from the mean, 0″·3.

These are from measures of the positions of belts, zones, and spots, and are the resulting polar diameters of Jupiter. Mr. Crommelin's computed value for mean noon was 42″·1.

In the following measures of the position of the belts, &c., on the disc of Jupiter no correction has been applied for the jovicentric latitude of the Earth above the equator, but all have been reduced to mean distance Δ5″·20.

The S.S. Temperate Band (0).

As this band was seldom well seen very few measures of its position were obtained. The last column gives the longitude of the central meridian at the time of observation.

1898.		
Mar. 14	−11″·6	240°
May 11	−11·4	200

e. the measures were made when the longitude of the central meridian of the apparent disc was 240°, &c.

The S. Temperate Band (1).

1898.			1898.		
Mar. 6	−7″·6	130°	Mar. 31	−8″·1	230°
10	−7·6	30		−7·7	280
14	−6·1	240	Apr. 4	−8·0	170
19	−8·8	300	12	−8·1	180
20	−7·7	90		−7·5	200
21	−7·7	210	May 6	−7·8	240
23	−7·7	150		−8·4	180
30	−7·6	160	11	−8·1	200
	−7·6	190			

Means: 1897–8, −7″·8; 1896–7, −8″·2; 1895–6, −8″·7.

The S. Equatorial Belt (2).

This is the S. component of the double band just S. of the equator.

1898.			1898.		
Mar. 6	−4″·0	130°	Mar. 22	−4″·6	0°
10	−4·7	30	23	−4·8	150
14	−4·1	240	31	−4·4	230
19	−5·0	300		−3·9	280
20	−4·0	20		−4·9	320
21	−5·9	210	Apr. 5	−5·0	260

Means: 1897–8, −4″·6; 1896–7, −5″·4; 1895–6, −5″·7.

The measures were made from the middle of the band; those in 1895–6 from the S. edge of the band.

The S. Equatorial Belt (2, 3).

The measures were made from the middle of 2, 3, or from the bright streak between them.

1898.			1898.		
Mar. 14	−4″·1	240°	May 6	−3″·2	240°
31	−3·6	230	11	−3·1	200
Apr. 12	−3·3	200	18	−3·8	200

Means: 1897-8, −3″·5; 1896–7, −3″·4; 1895–6, −3″·9.

The N. Equatorial Belt (4).

(Double in 1896–7; single in 1897–8.)

1898.			1898.		
Mar. 8	+4″·0	90°	Mar. 31	+4″·6	230°
10	4·5	30		3·3	280
14	3·8	240	Apr. 4	3·1	150
19	4·4	300	5	3·3	260
20	3·8	20	12	2·7	220
21	3·4	210	May 6	3·4	200
22	3·8	0		3·6	240
23	4·0	150	11	3·3	200
30	+3·2	190	18	+2·9	180

Means: 1897–8, +3″·6; 1896–7, +4″·1*; 1895–6, +2″·4.

In 1895–6 this belt was "inconspicuous in all longitudes, and was seldom well seen."

* N. edge = 6″·0.

The N. Temperate Band (5).

1898.			1898.		
Mar. 21	+7″·5	210°	Apr. 4	+7″·5	170°
30	6·3	160	12	+7·0	200
	+6·6	190			

Means: 1897–8, +7″·0; 1895–6, −7″·4.

The N.N. Temperate Band (6).

1898.		
Mar. 14	+10″·1	240°
20	+9·9	90

Mean: +10″·0.

The Equatorial Zone (*c*).

The measures were made from the middle of this zone to the N. and S. poles: difficult and uncertain.

1898.			1898.		
Mar. 30	+0″·6	160°	Apr. 8	+″·6	0°
31	·3	230	12	·6	200
	·3	280	May 11	·7	200
Apr. 4	+·6	150	18	+0·8	200

Means: 1897–8, +0″·6; 1896–7, +0″·3.

The Middle of Zone b.

1898.			1898.		
Mar. 30	−5″·7	160°	Apr. 4	−5″·2	20°
31	5·7	250	12	6·4	200
	5·9	280	May 18	−6·4	180

The mean is −5″·9.

The Middle of Zone d.

1898.		
Apr. 4	+5″·2	170°

The Dark Spots a, b, c.

1898.			1898.		
Mar. 6	+5″·7	*a*	Mar. 30	+5″·6	*a*
8	5·2	*a*		5·6	*a*
14	5·2	*c*	31	4·3	*c*
19	4·7	*c*		4·8	*c*
20	5·7	*a*		5·1	*c*
21	4·7	*b*	Apr. 12	4·9	*c*
23	5·4	*a*	May 18	+4·5	*b*

Mean: 1897–8, +5″·1.

The three spots were probably not in exactly the same latitude; at any rate the distances of their centres from the N. edge of band 4 were not quite the same.

Measures of the Breadth of Bright Zones and Dark Spots, &c.

The Equatorial Zone (c),

i.e. the width from the N. edge of band 3 to the S. edge of band 4. The last column gives the longitude of the central meridian at the time of observation.

1898.	″	°	1898.	″	°
Mar. 8	4·0	90	Mar. 30	3·7	160
19	3·9	300	31	3·4	230
20	3·5	110	Apr. 8	3·4	0
21	3·2	210	12	3·3	200
23	3·8	110	May 6	4·2	190
30	3·7	160			

Means: 1897–8, 3″·6; 1896–7, 3″·0.

The last column, as before, gives the longitude of the centra. meridian at the time of observation.

The S. Tropical Zone (b).

1898.	″	°	1898.	″	°
Mar. 21	2·3	240	Mar. 31	1·3	250
23	1·3	110	Apr. 12	1·2	200
30	1·7	150			

Means: 1897–8, 1″·4; 1896–7, 1″·7.

The N. Tropical Zone (d).

1898.	″	°
Mar. 23	1·7	110
May 6	1·8	190

Breadth of 2, 3, the Central Zone c, and 4,

i.e. from the S. edge of band 2 to the N. edge of band 4.

1898.	″	°	1898.	″	°
Mar. 6	9·6	130	Mar. 30	8·2	190
8	9·4	90	31	8·1	230
10	9·1	30	Apr. 4	8·1	150
19	8·3	300	8	8·2	0
20	8·3	20	12	8·0	200
	8·5	110	May 6	7·5	180
21	8·1	210		7·6	200
22	8·2	0		8·0	220
23	8·5	110	11	7·4	200
30	8·2	160			

Means: 1897–°, 8″·3; 1896-7, 10″·9.

Breadth of 2, 3,

i.e. the double *S. equatorial belt* and the narrow bright space between them.

1898.	″	°	1898.	″	°
Mar. 6	3·6	110	Mar. 30	3·3	130
8	4·1	98	31	3·4	230
10	3·3	30	Apr. 4	3·7	140
14	4·1	250	8	3·4	20
19	3·3	300	12	3·3	203
20	3·5	20	May 6	3·8	180
21	3·6	207		3·1	151
23	3·7	120			

Means: 1897–8, 3″·5; 1896–7, 3″·8.

Breadth of the N. Equatorial Belt (4).

This band was double during the opposition 1896–7.

1898.	″	°	1898.	″	°
Mar. 8	1·3	90	Mar. 30	0·9	160
14	1·6	240	31	1·2	230
19	1·4	300	Apr. 8	1·2	320
20	1·2	110	12	1·2	203
21	1·2	210	May 6	1·6	211
23	1·2	110			

Means: 1897–8, 1″·3; 1896–7, 3″·9.

Breadth of the South Temperate Band (1).

1898.	″	°
Mar. 31	1·3	250
May 6	1·6	211

Means: 1897–8, 1″·4; 1896–7, 1″·1.

This was always a difficult band to measure; and along with the measure on March 21 is given the remark, "Width of band 1=about $\frac{1}{3}$ of width of zone *b*." On April 12 the note occurs, "8^h: 1 is nearly as wide as zone *b*;" and on May 12, 7^h to 8^h, "1 is very faint and indistinct and narrow—quite unlike its general appearance;" a wider and darker portion began to approach the central meridian about 11$\frac{1}{2}^h$. On March 21, when the longitude of the central meridian was 210°, the measure was 0″·7, very different from that on May 6.

The Dark Spots.

1898. *a*. March 6. Length, 5″; distance of middle of spot from the N. edge of band 4=2″. The spot was about half an hour in passing the central meridian.

1898. *b.* March 14. Length about 1″.
1898. *c.* March 14. Length, $3\frac{1}{2}$″; time taken in passing the central meridian on March 14 and 31, about 20 minutes. A measure of the length on March 19 was 3″.

These were all difficult objects to measure, even on good nights.

OBSERVATIONS OF PHENOMENA OF *Jupiter's* SATELLITES WITH THE 9-INCH COOKE EQUATORIAL REFRACTOR.

Day of Obs. 1897.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation. h m s	G.M.T. of *N. Almanac.* h m s
Oct. 20	I. (*a*)	Ec. D.	Fading	17 22	17 23 35
			Just gone	17 23 27	
1898. Feb. 21	II. (*b*)	Ec. D.	Fading	12 22	12 25 27
			Bisected?	12 24 30	
			Just gone	12 25 31	
	I. (*b*)	Ec. D.	Fading?	14 23	14 24 14
			Bisected?	14 24	
			Just gone?	14 25	
23	II. (*c*)	Tr. E.	External contact	11 4	11 3
	I.	Oc. R.	External contact	11 45	11 46
Mar. 2	III. (*d*)	Tr. I.	External contact	10 6	10 10
			Bisection	10 9	
			Internal contact	10 13	
	III.	Tr. E.	Internal contact	12 22	12 33
			Bisection	12 28	
			External contact	12 33	
	III. (*d*)	Sh. E.	Internal contact	10 30	10 38
			Bisection	10 34	
			Just off	10 36 30	
	I. (*e*)	Ec. D.	Fading	10 43	10 45 50
			Bisection	10 45 30	
			Just gone	10 46 0	
	II.	Tr. I.	External contact	10 47 30	10 51
			Bisection	10 49	
			Internal contact	10 52	
	II. (*f*)	Sh. E.	Internal contact	12 14	12 18
			Just off	12 17	
	II.	Tr. E.	Internal contact	13 12	13 19
			Bisection	13 14	
			External contact	13 16	

Day of Obs. 1898.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation. h m s	G.M.T. of *N. Almanac.* h m s
Mar. 3	I. (*f*)	Sh. E.	Internal contact	10 12	10 12
	I.	Tr. E.	Internal contact	10 37	10 42
			External contact	10 43	
10	I.	Sh. E.	Internal contact	12 5	12 6
			Bisected	12 6	
	I.	Tr. E.	External contact	12 27	12 27
20	III. (*g*)	Oc. D.	External contact	8 57	8 56
May 3	I.	Oc. D.	External contact	8 29	8 29
			Bisection	8 31	
			Just gone	8 32	
	I.	Ec. R.	First seen	11 31 58	11 32 11
			Bisection?	11 33	
			Full?	11 36	
4	I. (*h*)	Tr. E.	Internal contact	7 59	8 2
			Bisection	8 1	
			External contact	8 3	
	I.	Sh. E.	Internal contact	8 49	8 53
11	I.	Tr. I.	External contact	7 36	7 35
			Internal contact	7 40	
12	I.	Ec. R.	First seen	7 55 36	7 55 11
			Full?	7 58	
14	II. (*i*)	Ec. R.	First seen	8 56 1	8 56 6
18	I.	Tr. I.	External contact	9 24	9 24
			Bisection	9 27	
			Internal contact	9 29	
	I.	Sh. I. (*j*)	Internal contact	10 30	10 28
June 10	I.	Tr. I. (*j*)	External contact	9 28	9 27
			Internal contact	9 33	
	III.	Tr. I. (*j*)	External contact	10 24	10 23
			Internal contact	10 29	
	I. was on the central meridian about $10^h\ 33^m$				
17	IV.	Tr. I.	External contact?	9 30	9 45
28	III. (*k*)	Oc. D.	External contact	8 17 30	8 17
			Bisection	8 20	
			Just gone	8 23	
July 9	Shadow of III. on central meridian about $8^h\ 30^m$				
11	I. (*l*)	Oc. D.	External contact		8 45

Notes.

(*a*) Planet low; strong twilight. (*b*) Clouds passing. (*c*) Much boiling. (*d*) Very difficult and uncertain, owing to motion and to fact that the ingress occurred near N. pole. (*e*) Clouds passing. (*f*) Much boiling on limb. (*g*) Bad definition. (*h*) Much motion. (*i*) Very bad definition. (*j*) Bad definition. (*k*) Bright sunshine; much motion. (*l*) Much motion.

Powers used 150 and 240.

NOTES ON CERTAIN PHENOMENA PRESENTED BY *Jupiter's* SATELLITES AND THEIR SHADOWS DURING TRANSIT ACROSS THE DISC.

1898 March 2. III. When the shadow of this satellite was approaching the W. limb (egress) it was large, black, and elongated in a direction parallel to the belts. The satellite passed on to the disc about $10^h\ 9^m$; at $10^h\ 50^m$ it was seen as a dusky or grey spot; became invisible about $10^h\ 20^m$; and reappeared as a bright object about $12^h\ 10^m$. It moved along the S. edge of the N. polar shading. Sat. II. was invisible at $11^h\ 2^m$.

March 3. I. in transit; it was invisible at 9^h, and so remained till $10^h\ 20^m$.

March 10. I. in transit. It was invisible at $10\frac{1}{2}^h$, and so remained till $12\frac{1}{4}^h$.

May 11. I. in transit. The satellite moved along the bright zone *d*, *i.e.* the N. tropical zone. It was a bright object on the disc at $7^h\ 45^m$; then faint; invisible at 8^h; reappeared at $8^h\ 10^m$ as a very faint grey spot; much darker at $8\frac{1}{2}^h$; as black as a shadow at 9^h, and so remained till after 10^h, when cloud and rain stopped further observation. It was on the central meridian about $9^h\ 27^m$.

May 18. I. in transit, moving along the bright zone *d*. Ingress about $9^h\ 27^m$; $9\frac{1}{2}^h$ fainter; $9^h\ 40^m$ much fainter; $9^h\ 45^m$ just visible; $9^h\ 50^m$ invisible; 10^h just visible as a grey spot; $10^h\ 10^m$ a little darker; 10^h to $10\frac{1}{2}^h$ a grey spot, not dark. It had grown no darker at 11^h and $11\frac{1}{2}^h$, when clouds prevented further observation.

June 10. I. in transit, moving along the bright zone *d*. Ingress about $9^h\ 33^m$; $9^h\ 35^m$ fainter; $9^h\ 50^m$ just visible; 10^h invisible; $10^h\ 10^m$ a grey spot, and there was no further change up to 11^h. It was on the central meridian about $10^h\ 33^m$.

Sat. III. in transit moving along the S. edge of the N. polar shading; at 11^h it was very faint indeed.

June 17. IV. in transit moving in the grey N. polar region, and not far from the pole; at $9^h\ 33^m$ it was perhaps just fully on the disc; $9^h\ 40^m$ invisible; $9^h\ 50^m$ a faint grey spot; 10^h spot a little darker; $10^h\ 10^m$ still darker, and so it remained till $10^h\ 30^m$, when clouds hid the planet; it was not black.

Observations of the Variable Stars (2100) *U Orionis and* (4896) *T Centauri.* By Colonel E. E. Markwick.

U Orionis.—There has been some discussion as to the length of period of this star, which is even now to a certain extent unsettled, although better known than when the data were more limited, for the star has only been observed as a variable since 1885 December 13, when it was first discovered by Mr. Gore. The discoverer made the period 373·47 days (see *Monthly Notices*, vol. l. p. 518). Dr. Chandler in his 2nd Cat. of Variable Stars gave 371 days, with periodic inequality. In the 3rd Cat. this period is changed to 375 days, and I think from what follows this latter period is not far from the truth.

I have observed this star at every period of maximum from 1886 to 1898, except the year 1893, when only one observation was made. The observations have been made usually with a binocular magnifying five times, supplemented by a $2\frac{3}{4}$-inch refractor. My "date of maximum" is the day on which the star's brightness, when reduced from the comparison stars, was actually greatest. It has not been taken symmetrically as regards the light curve near time of maximum.

The comparison stars and brightness are as follows, the latter being mostly adopted from the *Harvard Photometry* :—

		m.
D.M. + 20	1156	6·57
+ 19	1126	5·85
+ 19	1110	6·08
+ 20	1171	8·2
+ 20	1168	8·6
+ 20	1172	10·0
χ^1 Orionis		4·65
χ^3 „ (Proctor) = H.P. 1119		5·08

The light curve of this star is very flat near maximum, hence there are bound to be considerable divergencies between the results of different observers. I have therefore taken the mean of my own and all the observations to be found in the summaries of astronomical publications given in the *Journal* of the *B. A. A.* The following table shows my dates of maximum with observed brightness, also the mean of all the observed dates of maximum from 1892, this portion being a revision and continuation of the table at p. 531 of *Monthly Notices*, vol. liv. The last column gives the interval in days between these mean results :—

Observed Date of Maximum.	Mag.	Mean of all Observations.	Interval in Days.
1886 December 16	6·12	...	...
1887 „ 16	7·26	...	...
1888 „ 29	5·49	...	...
1889 (no maximum)	...	...	...
1890 January 16	6·27	...	...
1891 „ 9	6·3	...	...
1892 „ 23	6·27	January 31	376
1893 (not observed)	...	February 10	369
1894 February 8	6·07	„ 14	377
1895 „ 24	6·08	„ 26	386
1896 March 19	6·27	March 18	360
1897 „ 11	5·61	„ 13	384
1898 „ 31	6·33	April 1	...
		Mean	375·3

Also, if we take the interval between two well-determined and most widely separated maxima, and divide by the number of periods elapsed, we get exactly the same result again. Thus :—

	Julian.
1886 December 12	241,0253
1898 April 1	241,4381
Difference ...	4128
Dividing by 11 ...	375·3

It seems very probable, therefore, that at present we cannot better this.

The following table shows the comparison of observation and computation based on this period of 375·3 days. It will be observed that the residuals are fairly small except for 1894, 1896, and 1897, in each of which years moonlight was present and probably affected determinations of maximum brightness :—

	Maximum.		
Year.	Computed.	Observed.	O−C
1886	0252	0253	+1
1887	0628	0626	−2
1888	1003	1001	−2
1889	1378	1377	−1
1891	1754	1752	−2
1892	2129	2129	0
1893	2504	2505	+1
1894	2879	2874	−5
1895	3255	3251	−4
1896	3630	3637	+7
1897	4005	3997	−8
1898	4381	4381	0

The only thing that militates against this period is the fact that it does not fall in so well with the ancient dates referred to by Chandler in the *Astronomical Journal*, No. 233, p. 133, as when the period 373·47 days is used. The omission of the star from the observations of Lalande, Bessel, &c., would imply that at those dates it was probably in its fainter stages of brightness. Using a uniform period of 375·3 days, the following shows the distance in time each observation of neighbouring stars was before or after maximum :—

No.	Authority which failed to observe the Star.	Date of Observation of Vicinity.	Difference in Days from Computed Maximum.
1	Lalande	1797 February 17	152 before
2	Bessel	1826 March 3	56 „
3	Markree Observatory	1850 December 30	5 after
4	Schönfeld	1853 November 6	79 before
5	Markree	1854 „ 24	71 „
6	Schönfeld	1855 February 18	15 after
7	Krüger	1857 „ 9	14 before

In the case of 3, 6, and 7, supposing the period of 375·3 days correct, then the star was not far from maximum at these dates, and probably not below 7 m. Hence it is difficult to say why the star was missed ; yet at the same time too much stress must not be laid upon negative evidence. In the other four cases the star was sufficiently far from maximum to account for its being missed.

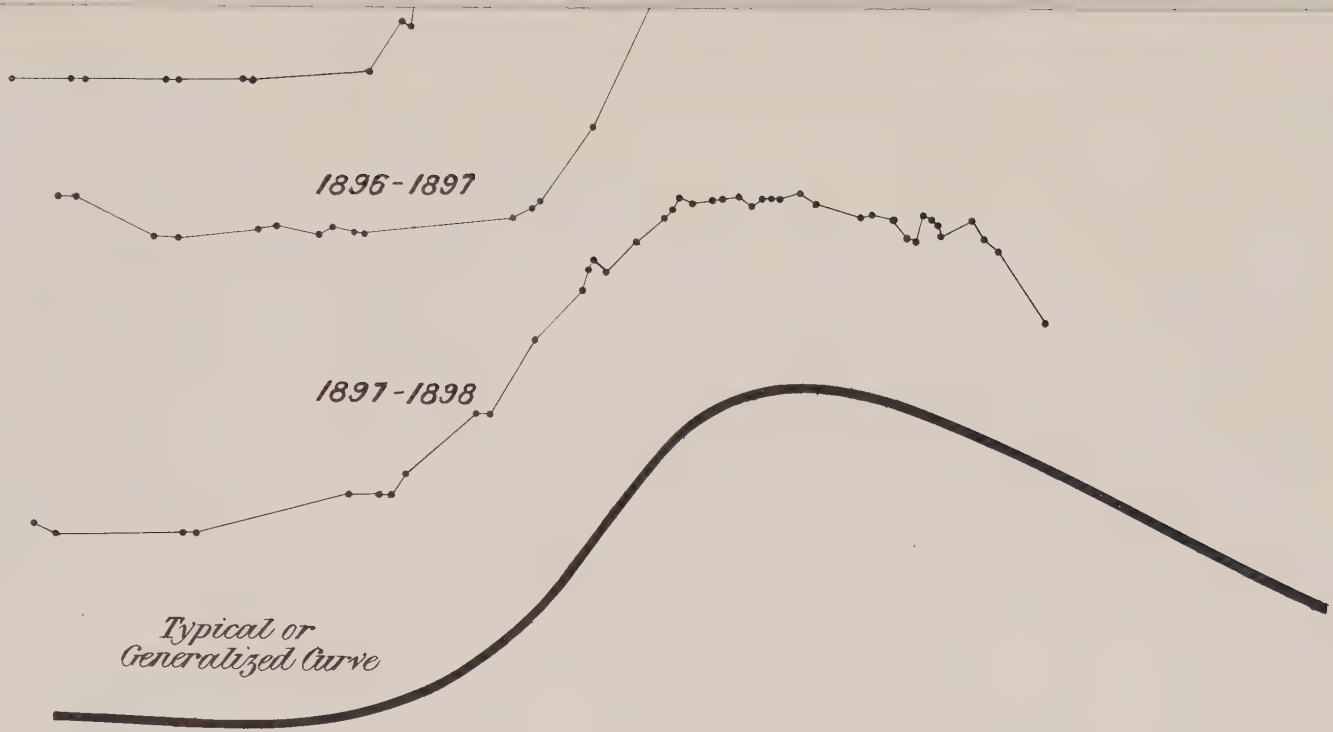
Plate 7*a* shows the observed brightness for eleven seasons, based on my own determinations alone.

These amount altogether to 307 in number.

The proportion adopted between length representing time (abscissa) and length representing brightness (ordinate) is ten days = 1 magnitude.

Many of the apparent irregularities or departures from a mean curve thus revealed are doubtless due to errors of observation from the various causes which constantly hamper the observer of variable stars. Apart from these, however, some of the fluctuations noted I am convinced are real. For example, in nearly all the curves just after the maximum there is a drop, and then a small recovery, which probably actually occurs. Mr. Peek shows a similar feature in his observations of *S Ursæ Majoris* (Variable Star Notes, No. 3).

I have added a typical or generalised curve, which is a rough mean of all the others, to give a general idea of the star's variation, but I am no believer in smoothed curves, and am confident that in nature gradual increase or decrease in light is subject to certain minor irregularities or fluctuations, which, however, cannot always be easily detected, owing to their minuteness. I do not see any more reason for the curve of light variation being smooth than that of the waxing and waning of sun spots.



OBSERVATIONS OF U ORIONIS.

T Centauri.—This star, the variability of which was first detected by me at Gibraltar in 1894, has been observed as frequently as possible since. Mr. Roberts has investigated the period (see *Monthly Notices*, vol. lvi. pp. 347 and 500) and shape of the light curve, and from what follows I do not think that his period of 91·5 days can be improved upon.

My observations were made in the same way as those of *U Orionis*. Comparison stars, with brightness :—

L 5649	7·0 m.
244 (U.A.) Centauri	7·0
237 Centauri	6·7
241 {L 5613, L 5615} Centauri	6·8
286 Centauri	6·0
267 Centauri	5·8
287 Centauri	6·6
233 Centauri	6·8 (var.)
A	7·4 } These two stars are s.p. L 5649 at a little greater distance than that separating T from L 5649.
B	7·8 }
C	10 R.A. 13h 34m·6, Dec. −33° 7′ (1875), 8·8 in C.D.M.
D	10·2 R.A. 13h 34m, Dec. −33° 0′, 8·4 in C.D.M.

The observations of maxima, together with the deduced period, are shown in the following table :—

	Mag.	Interval.	Corresponding Length of One Period.
1894 May 25	6·25	} 379	
1895 June 8	5·3		94·7
		} 376	
1896 June 18	6·4		94·0
		} 348	
1897 June 1	6·17		87·0
		} 367	
1898 June 3	6·6		91·7
	Mean		91·85

Also if we take the interval from the first to the last of these determinations we get 1,470 days, corresponding to a period of 91·9 days.

The observations of minima, which, however, are not so definite as those of maxima, are as follows :—

		Interval.	Corresponding Length of One Period.
1894 July 24	<8·5	} 276	
1895 April 26	10·0		92·0
		} 370	
1896 April 30	9·9		92·5
		} 718	
1898 April 18	9·2		89·8
	Mean		91·4

Also from the first to the last of these dates is 1,364 days, corresponding to fifteen periods of 90·9 days each.

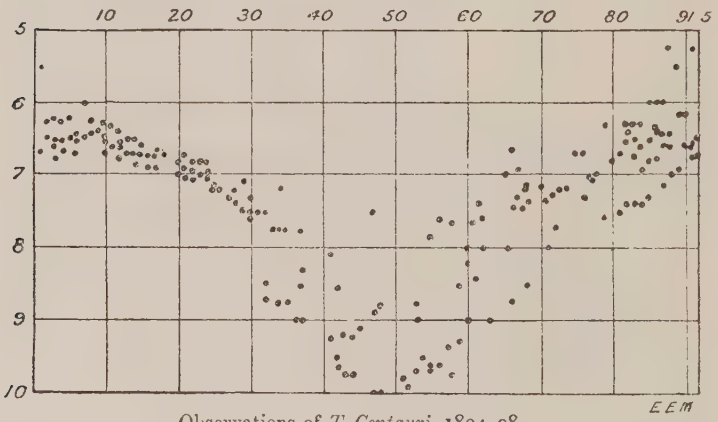
The mean of these four determinations is 91·51 days.

With the adopted period of 91·5 days the residuals come out as follows :—

	Maximum (Julian).		
Year.	Computed.	Observed.	O−C
1894	2988	2974	−14
1895	3354	3353	− 1
1896	3720	3729	+ 9
1897	4080	4077	− 3
1898	4446	4444	− 2

There are but few observations of this star to hand, as it can only be reached from the extreme south of Europe. Mr. Tebbutt observed a maximum on 1896 March 8. This is only one day before the computed time.

Another maximum was observed and recorded in *A. J.*, 49, as on 1897 May 29. This is six days before computation.



Observations of *T Centauri*, 1894–98.

Based on the 91·5-day period all the observations of my own, in No. 203, have been plotted according to phase, *i.e.* to the length of time elapsed from next preceding maximum. The general shape of the light curve is at once apparent, the minimum occurring some forty-eight days after maximum, thus practically agreeing with Roberts's result, forty-nine days.

Unless some long-continued and egregious blunders in determination of brightness have been made, it is plain that the intrinsic brightness varies in different periods, and to a considerable extent. One can trace two, if not more, lines in the ascending branch. Hence I do not think the light curve is ever so smooth

and regular as that given by Roberts at p. 350 of *Monthly Notices*, in the first of the papers previously referred to. The brightness undoubtedly varies in different periods, and I think the general curve is subject to minor irregularities, as in the case of *U Orionis*.

Observations of Nebulæ. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

The following notes are in continuation of those published in the April, 1898, number of the *Monthly Notices*, and were made in the course of my observations upon nebulæ, during the first six months of 1898. The numbers, as previously, are the current ones of the N.G.C., except those which are enclosed in brackets, which refer to Dreyer's Index Catalogue in vol. li. of the *Memoirs of the R.A.S.* When, instead of a number, the name Swift is given, reference is made to objects recently discovered at the Lowe Observatory, found in lists published from time to time in various periodicals, chiefly in the *Monthly Notices*.

As the positions of so many of the nebulæ in my working list are erroneous, because of the inaccurate places given by the discoverers, I have striven not to add new errors by mistakes of my own, and have therefore determined the position of each comparison star twice, once by means of the circles of the instrument, and a sidereal watch, and a second time by connecting it with some catalogue star by chronographic and micrometric measures. There are two checks against gross errors in the micrometric measurements between each nebula and its comparison star. These are, firstly, independent estimates of $\Delta\alpha$ and $\Delta\delta$ by the help of the known intervals between the micrometer wires, and, secondly, sketches of the field of view. In a few cases a larger telescope, or a keener eye, may be needed to settle doubtful points. All positions are referred to the mean equinox of 1900·0.

The new Bruce micrometer, to which reference was made in my former communication, has now been in use for six months, and has proven itself to be a most admirable instrument. It has a set of eleven wires in R.A., and nine in declination, the latter spanning a space of 30′ ; the sets can be illuminated separately or simultaneously, with any desired intensity. The micrometer screw has movable heads, so that three bisections can be made before the readings are taken. The box can also be revolved just 90°, without reading the position-circle.

(195) and (196). These two nebulæ were not at all difficult to see, and I found no others in their neighbourhood. Hence I assume the ones which I observed to be those found by

Swift, though their relative positions are not as given by him. Their positions are :—

$1^h\ 58^m\ 20^s$, $+14°\ 13'{\cdot}7$,
$1^h\ 58^m\ 25^s$, $+14°\ 15'{\cdot}5$.

1121. The position is $2^h\ 45^m\ 35^s$, $-2°\ 8'{\cdot}8$.

1337. Swift described this as "m E n s." I estimated the elongation to be at 135°.

(346). I measured (345), and its place agrees with that given by Dreyer within 1′. But in the place of (346), which was presumably discovered by Professor Stone at the same time, I saw nothing but faint stars. The seeing was excellent, and Professor Stone described (346) as brighter than (345).

1489. The position is $3^h\ 53^m\ 11^s$, $-19°\ 30'{\cdot}3$.

1518. The elongation is at 200°. The position is $4^h\ 2^m\ 29^s$, $-21°\ 26'{\cdot}6$.

1561–5. I could not see all the nebulæ in this group, but found a new one near by. Since the positions of these nebulæ are poor, a large telescope may well give attention to them.

1592. In the place given for this I found only small stars. 1591, near by, was observed.

1614. The position is $4^h\ 29^m\ 11^s$, $-8°\ 47'{\cdot}3$.

1619. In the place given for this I saw only stars of mags. 13–14. Its neighbour, 1627, was readily seen.

1689. Swift called this "pB." I searched for it on two nights without success. Probably there was an error of just 5^m in its R.A., and it is identical with 1667, which has the same declination.

1729. The N.G.C. description is "vF, pL, 2 B st v nr." My description was "F, pS, R, with nucleus of mag. 13·5." It is in line between two stars of mags. 8·5 and 9 respectively, the former preceding it $20^s\pm$, on nearly the same parallel, and the latter following it 4^s.

1738. The position is $4^h\ 57^m\ 22^s$, $-18°\ 18'{\cdot}1$.

1739. The position is $4^h\ 57^m\ 23^s$, $-18°\ 18'{\cdot}7$.

1744. This is very large, faint, and ill defined. But it contains a nuclear point of mag. 12·8. The position is $4^h\ 55^m\ 52^s$, $-26°\ 10'{\cdot}4$.

1781. On two nights I was unable to find this, though I measured 1794, which is similar in description. As the N.G.C. R.A. of 1781 differs from my R.A. for 1794 by 3^m, and the declinations of the two objects differ by less than 1′, it is probable that H. made an error of 3^m in the place of 1781.

1794. The position is $5^h\ 3^m\ 31^s$, $-18°\ 19'{\cdot}2$.

2054. I saw only three small stars. The 9 mag. star which Bond said to be 7′ north was seen.

2124. H.'s description is "eeF, pS, E, r," while I called it simply "F, S." However, I noticed a star of mag. 14 just south, and one of mag. 13 40″ further south. A rude representation of the nebula, which I drew, makes it elongated at 180°. Its position is $5^h\ 53^m\ 33^s$, $-20°\ 5'{\cdot}6$.

Swift. This is in Swift's List No. 6. Its position is $5^h\ 53^m\ 43^s$, $-23°\ 11'{\cdot}4$.

Swift. This is in Swift's List No. 6. Its position is $5^h\ 56^m\ 59^s$, $-23°\ 40'{\cdot}5$.

2179. *h.* described this as "vmE." I looked carefully for elongation, and could perceive none. Two 12 mag. stars flank the nebula, on opposite sides; perhaps *h.* thought them to be portions of the nebula.

2206. This contains a 13·5 mag. double star, whose angle is 80°, and distance 10″.

2207. This is binuclear at 260°; the following nucleus is the brighter.

2211. The position is $6^h\ 14^m\ 8^s$, $-18°\ 29'{\cdot}8$.

2237. This seems to be the brightest point in a large nebulous region, which covers the entire background of the sky in this vicinity, though not with even brilliancy. Swift described it as a part of a ring surrounding a cluster. This appearance I could not verify, possibly because my field of view is much smaller than his. The position is $6^h\ 25^m\ 21^s$, $+5°\ 4'{\cdot}9$.

2280. *h.* described this as "lE." It appeared to me to be very narrow, and elongated at 160°, the southern end being extremely faint, and terminating at or near a star of mag. 13·5. But the definition was poor when I observed it, so that I may have missed faint lateral nebulosity, which would make the nebula appear less narrow.

2295. This nebula precedes the double 2292–3, instead of following it. The note in the N.G.C. should read, "D neb f." In other particulars the N.G.C. descriptive notes on these nebulæ agree with my observations. The position of 2295 is $6^h\ 43^m\ 23^s$, $-26°\ 37'{\cdot}6$.

2292. The position is $6^h\ 43^m\ 39^s$, $-26°\ 38'{\cdot}1$.

2293. The position is $6^h\ 43^m\ 42^s$, $-26°\ 38'{\cdot}6$.

2296. The position is $6^h\ 44^m\ 12^s$, $-16°\ 47'{\cdot}3$.

(454). One or two stars are involved in this nebula. Its position is $6^h\ 45^m\ 28^s$, $+13°\ 2'{\cdot}4$.

2325. *h.* called this "lE." To me it appeared round, with two 13 mag. stars near by, on opposite sides of it, at angles of 160° and 340° respectively.

2327. The double star involved in this very faint nebula is of mags. 9 and 12, at an angle of 110°, and distance of 7″.

(468). This nebula of Bigourdan's is supposed to precede 2361 by a little over 1^m. But I could not find any such object, though I examined the vicinity on three nights.

2359 and 2361. In the N.G.C. 2359 is called "vv L," but there is apparently an error of 1^m in its R.A. When Bigourdan discovered 2361, he probably thought it different from 2359, because the R.A. which he obtained was 1^m different. 2361 is really a small condensation in 2359. I examined these objects on three nights, one of which was exceptionally fine.

2382. I searched for this on two nights (on one of which the definition was good) in vain; on each occasion I saw 2380, which has a similar description, and was an easy object. I called it "pB, with good nucleus."

2409. This consists of ten scattered stars.

2438. In the N.G.C. this is described as a planetary nebula. I found it to be nearly uniform in brightness, but darker in the centre. It contains two stars of mags. 13 and 14 respectively, and many more were suspected. It is slightly elliptical at 135°. It lies in the elegant cluster 2437, and is one of the prettiest objects in the sky.

2440. In the N.G.C. this is described as a planetary nebula, which is not very well defined. I found it to be binuclear at 160°. There is also a very faint condensation at the preceding end of the nebula. The object is small, greenish, and very bright.

2470. The elongation is at 120°. A double star of mag. 9, angle 220°, and distance 3″, precedes it 11^s, 1′·4 north.

2491. Swift calls this "eeF," and puts it 15^s preceding 2496, and following a "B ∗." 2496 was easily found near the place assigned for it; the "B ∗" appeared to be of mag. 10, and 2491, after careful scrutiny on a fine night, resolved itself into a few stars of mag. 14.

2496. My description tallies with Swift's, except that he says "∗ close f," while I found a star of mag. 11, 3^s preceding.

(487). Swift described this as round; it is elongated at 110°.

2506. *h.* corrected his N.P.D. of this object by −10′, to make it agree with that found by Harding and H., and the N.G.C. has followed him. As the cluster, when searched for, was evidently not at this N.P.D., I took a single careful reading of the declination circle, which put it 10′ farther south. The N.P.D. should therefore be 100° 24′·4 in the N.G.C.

2564. This is described in the N.G.C. as "vF, S, R, gbM." I found it to be extremely small, and elongated at 90°; it looked quite like a faint close double star.

2566. The N.G.C. description is "vF, cL, er." I found here two objects of mags. 11 and 12 respectively. The brighter one is certainly a very small nebula, or nebulous star. I could not be certain that its nebulosity extended to the 12 mag. star. This object was examined on three nights, two of which were fine.

2610. The 7·5 mag. star near this nebula is Schjellerup 3139, the catalogue position of which agrees with the circle-readings of my instrument; there is no other bright star in the neighbourhood. Therefore the N.G.C. place of the nebula is erroneous. The correct position is $8^h\ 28^m\ 42^s$, $-14°\ 53'·8$.

2616. Swift called this "R." To me it appeared elongated at 180°, having the appearance of a very faint nebulous double star, having a distance of 10″.

2662. I searched in vain for this, in the place given in the N.G.C., on three nights, and finally found it 10′ north of its supposed location. The star mentioned by *h.* is of mag. 13, and precedes 2^s, a trifle north. The position of the nebula is $8^h\ 40^m\ 52^s$, $-14°\ 45'·4$.

2690. The position is $8^h\ 47^m\ 35^s$, $-2°\ 13'·6$.

2848. In measuring this I bisected the brightest spot in it; perhaps that is 2847. Dreyer saw a star of mag. 11–12, 3′ n.f.; I saw two stars there, n.f. the brightest part of the nebula, near its edge, and possibly involved in it.

2978. The position is $9^h\ 38^m\ 23^s$, $-9°\ 17'·3$.

3143. The position is $10^h\ 5^m\ 10^s$, $-12°\ 5'·3$.

3292. The elongation is at 180°. The position is $10^h\ 30^m\ 33^s$, $-5°\ 39'·6$.

3321. The main body of the nebula appeared to lie about 15″ from the n.p. star (of mag. 12) which Leavenworth noted, at an angle of 135°. I was not sure that the nebulosity extended clear up to the star; I observed it on two nights. The position is $10^h\ 33^m\ 52^s$, $-11°\ 7'·4$.

3322. I searched for this on two evenings without success. On each evening 3321 was seen. Their descriptions are similar, and their right ascensions agree fairly; I am inclined to think them the same, though Common's approximate declination for 3322 differs from mine for 3321 by over 15′. There is a like discrepancy between his observations and mine in the case of his pair 3360–1.

3360 and 3361. I found the declination of 3361 to be $-10°\ 40'·9$, which is 14′ greater than Common's estimate. It is much elongated at 160°; a star of mag. 13 precedes it a trifle, and a 10 mag. star, which was suspected to be a close double at 130°, follows it several seconds, on nearly the same parallel. 3360 is round and very faint. It precedes 3361 about 10^s, 1′ or 2′ south. The R.A. of 3361 is between $10^h\ 39^m\ 25^s$ and $10^h\ 30^m\ 30^s$.

3404. The position given in the N.G.C. for this Common nebula is only approximate. I had only faint suspicions of a nebula in that position, and found a nebula near by, which, as it is pretty bright, and much elongated at 90°, I assume to be 3404. Its position is $10^h\ 45^m\ 20^s$, $-11°\ 34'·7$.

3421 and 3422. I could see nothing in the N.G.C. places for these Common nebulæ, on either of two nights. I found one very faint, round, and small nebula at $10^h\ 46^m\ 0^s$, $-11°\ 55'{\cdot}1$. The position of this was measured on two nights. A star of 12 mag. follows it about 4^s. On the first night I suspected an extremely faint nebula $1'{\cdot}5$ north of it. On the second night I suspected another preceding the known nebula 12^s, $2'$ south, but the definition was poor, and it may have been a star.

3546. The position is $11^h\ 4^m\ 47^s$, $-12°\ 50'{\cdot}1$.

3704. I have looked in vain for this on two nights, on each of which its neighbour 3707 was very easily seen and measured. It was called "pB" on one of the nights. I saw also the 9 mag. star which is said to be "$2'$ ssf" 3704. Yet both Tempel and Common call 3704 "vF," the same designation which they apply to 3707. Is it possible that 3704 is variable?

3711. The position is $11^h\ 24^m\ 22^s$, $-10°\ 31'{\cdot}3$.

3779 and (717). These nebulæ may be identical, since each discoverer obtained only an approximate place of his nebula. I saw with assurance only one nebula, though I suspected another between it and 3775. The position is $10^h\ 33^m\ 47^s$, $-10°\ 1'{\cdot}7$.

4038 and 4039. This is a remarkable double nebula. 4038 seems the larger. 4039 is elongated at 220° in comet fashion. 4038 has a faint condensation near its centre; two other condensations were suspected preceding and following it. Both are very diffuse, and at times their outlines appear to meet. The definition was only fair when these were examined.

4263 and 4265. I saw only one nebula here. It appeared to be elongated at 90°. I sometimes suspected that this elongation might be the result of duplicity, but the object was very diffuse, and gave no certain indication of doubling.

4722 and 4723. The N.G.C. place for these is only approximate, and Tempel evidently considered them as constituting a double nebula, each component being vF, vS. I found only one nebula, which was followed at an interval of 4^s by a star of mag. 11·5. The position of the nebula is $12^h\ 46^m\ 19^s$, $-12°\ 47'{\cdot}1$.

4726. The N.G.C. place of this nebula of Tempel's seems to be considerably out, both in R.A. and declination. The correct position is $12^h\ 46^m\ 18^s$, $-13°\ 40'{\cdot}6$.

4740. Near the place given for this in the N.G.C. are Nos. 4724, 4726 and 4727, together with a new one which I discovered. I could not find 4740, but found a nebula approximately $15'$ south and 20^s preceding, which tallied with Swift's description of 4740; (this is not the new one mentioned above). This entire region deserves careful

observation with a large telescope, because of the presumed errors in the places of 4726 and 4740.

Swift. In Swift's List No. 8, published in the 1898 March number of the *Monthly Notices*, is a nebula at $14^h\ 6^m\ 50^s$, $-30°\ 3'\ 33''$. Though he called it only "F," I saw nothing in this place, the nearest object being 5494, which is in the same field. They may be identical.

Swift. This is No. 25 in Swift's List No. 8 just mentioned. Its position is $14^h\ 28^m\ 39^s$, $-27°\ 4'{\cdot}8$.

(1077). The position is $14^h\ 51^m\ 43^s$, $-18°\ 48'{\cdot}6$.

(1081). The position is $14^h\ 53^m\ 16^s$, $-18°\ 50'{\cdot}4$.

5898. This has a fine nucleus. Its position is $15^h\ 12^m\ 22^s$, $-23°\ 43'{\cdot}9$.

(1115). Swift's description is "eeF, S, R, pB * sf." I found only a double star of mags. 12·5 and 13·5, with angle 315°, and distance 5″. A star of mag. 8·5 follows 7^s, 2′·5 south. The night was clear and the definition fair.

5926. The position is $15^h\ 18^m\ 41^s$, $+13°\ 4'{\cdot}3$.

6065 and 6066. Dreyer's note on these nebulæ, on p. 227 of vol. li. of the *Memoirs of the R.A.S.*, leads me to give their true positions. 6065 is at $16^h\ 2^m\ 45^s$, $+14°\ 9'{\cdot}3$. 6066 is at $16^h\ 2^m\ 57^s$, $+14°\ 12'{\cdot}7$.

6224. The position is $16^h\ 43^m\ 26^s$, $+6°\ 29'{\cdot}4$.

6225. A double, of 13 mag. stars, is involved; its angle is 90°, and distance 10″. The position is $16^h\ 43^m\ 29^s$, $+6°\ 24'{\cdot}0$.

6294. This follows 6293 closely, and appears to be simply a very faint double star of mags. 13 and 13·5, with an angle of 315°, and distance of 8″.

(1243). This was examined on two nights. It consists of five 12–14 mag. stars in a line, at an angle of 0°, the length of the line being 45″. A star of mag. 14 immediately precedes the northern end of the row.

6309. This is a close double nebula, at an angle of 160°. Both objects are extremely small, and are also bright.

6355. This appeared to be an extremely faint small round cluster of very small stars, having many outliers on the north, and some on the south also.

6401. This has a nucleus of mag. 13·5, at an angle of 315° from the 10·8 mag. star, which lies on the south following border of the nebula.

6476. I examined this region for quite a while, on a fine night. Large areas appeared to have a nebulous background, or else to be covered with myriads of very minute stars; I could not decide which was the case. I came across a small but striking "Loch im Himmel," at $17^h\ 55^m\ 0^s\pm$, $-28°\ 35'\pm$.

6526. This appeared to me not to be a nebula, but simply an aggregation of very faint stars.

(1290). This is simply a cluster of half a dozen small stars from mag. 12 down.

6717. The cluster in this nebula is composed of five stars of mag. 12. The southernmost two form a double of angle 0° and distance 3″. Two others form another double of angle 340° and distance 2″. The nebulosity surrounding these is very faint and formless.

Swift. In Swift's List No. 2, at $19^h\ 22^m\ 0^s$, $-36°\ 24'{\cdot}1$, there is an object which he described as "B, eS, vE, stellar, close nebulous D * ?." In this position I found nothing, but about 20^s preceding it there seemed to be a close double, the star being elongated at 100°.

6797. This was discovered by Peters, and was described as "a neb. with 9 mag. * att. f." I could see no trace of nebulosity, but the 9 mag. * was preceded by a double of mag. 13, angle 180°, and distance 10″.

6816. In this is a star of mag. 13·5. *h.* noted a " * np." I saw only a star of mag. 14 at an angle of 20° and distance of 30″. The sky was dull, so that the nebula was difficult to measure.

List of Nebulæ discovered at the Chamberlin Observatory, University Park, Colorado. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

While observing nebulæ and comets with the 20-inch refractor, I have from time to time chanced upon new nebulæ, a list of which follows. The positions of all, with one exception, have been micrometrically measured, and are given for 1900·0.

No.	Date.	R.A.	Dec.	Description.
	1895.	h m s	° ′	
1	Jan. 15	0 48 17	+ 5 13·7	eF, S, bet st 12^m and 13^m
2	15	0 49 32	+ 5 13·9	11^m nebulous ✶. 9^m ✶ p 10^s, 4′·5 n.
3	June 24	0 53 41	+ ⊙ 2·8	vF, eS, R, lbM.
4	July 3	1 21 41	− 4 1·3	12^m nebulous ✶. FD ✶ 2′ nf.
	1898.			
5	Jan. 14	4 18 7	−15 53·8	eF, vS. Near N.G.C. 1561–5.
6	Feb. 22	5 27 54	−13 59·9	vF, S. Near N.G.C. 1954 and 1957.
7	11	6 12 14	−21 20·4	eF, pS, f N.G.C. 2207 7^s.
8	16	8 14 31	−25 3·4	pB, vS, R, lbM, 6′ n of N.G.C. 2566.
9	22	8 21 37	−12 58·5	F, vS, elongated at 90°, 1st of 3.
10	22	8 21 44	−12 58·7	eF, vS, 2nd of 3.
11	22	8 21 45	−12 57·9	vF, vS, 3rd of 3.
12	Mar. 23	8 41 30	−14 59·4	vF, eS, lE.
13	Feb. 23	9 0 58	−18 48·4	F, vS, R, 10′ s of N.G.C. 2754, 2757, and 2758.
14	Apr. 25	11 10 32	−13 37·5	eF, S.
15	20	12 45 44±	−13 56	F, S, R, n of 11^m ✶.
	1897.			
16	Oct. 19	21 3 40	−23 17·1	eF, vS, diffic.
17	Sept. 30	21 34 15	−22 52·7	eeF, S, diffic. In field with N.G.C. 7103 and 7104. Another susp. 1′ s.
18	Oct. 20	22 7 0	−23 27·1	eF, vS, f N.G.C. 7220 63^s.
19	Sept. 27	23 15 30	−22 41·8	eF, eS, nearly stell., 13^m; 9·5^m, 5′ n.
20	28	23 18 55	−12 24·6	vF, vS, f 9·5^m ✶ 1′.
	1894.			
21	Dec. 14	23 29 28	− 5 5·2	nebulous ✶ 10·5^m. Possibly close D ✶. Extended nebulosity susp. at 135° and 315°.
	1897.			
22	Oct. 1	23 46 20	−13 56 2	F, vS, R, bM = ✶ 12·5^m.

Notes.

I would like to call the attention of observers with large telescopes to No. 22 of the above list. Its position is near those of N.G.C. 7761 and 7776, neither of which can I find. The position of N.G.C. 7761 was micrometrically observed by its discoverer, and its R.A. (1900·0) is $23^h\ 44^m\ 19^s$. The description of No. 22 tallies well with that of N.G.C. 7761, except that there is no 10^m * 8′ p. N.G.C. 7776 is supposed to follow No. 22 74^s, and is described as eF, vS, lE, gbM.

The following objects were not included in the preceding list, because their positions are not very accurate, and they were all looked for without success in 1897 October. The failure to see them at that time may, however, have been due to their extreme faintness.

Date.	R.A. h m s	Dec. ° ′	Description.
1894 Dec. 27	0 1 16	−0 38	eF, prob. S.
1895 Aug. 23	0 34 0	+5 25	eF, prob. S. Seen also on Aug. 24.
1895 Aug. 23	0 34 25	+6 4	nebulous *, prob. vF. Seen also on Aug. 24.
1894 Dec. 3	22 55 25	−8 40	eF, prob. S.

Observations of Comet h 1898 (Perrine-Chofardet) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the Sheepshanks equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time. 1898.	Observer.	✱ − ✱ R.A.	Corr. for Refraction.	Log Factor of Parallax.	✱ − ✱ N.P.D.	Corr. for Refraction.	Log Factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
d h m s		m s	s		′ ″	″			h m s	° ′ ″	
Sept. 21 16 24 14	A. C.	+1 59·33	−0·04	9·6115	− 8 58·2	−0·3	0·7936	4	10 29 40·60	64 12 14·0	*a*
21 16 21 6	,,	−2 46·70	+0·05	9·6116	+12 23·3	+0·4	0·7956	1	10 29 40·49	64 12 0·6	*b*

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

The initials A. C. are those of Mr. Crommelin.

Comparison Stars.

	Star's Name.	Assumed R.A. 1898·0.	Assumed N.P.D. 1898·0.	Authority.
		h m s	° ′ ″	
a	W.B. (2), X. 501	10 27 39·01	64 20 58·4	Cambridge Astr. Gesell. Catalogue and Paris Catalogue, 1860.
b	W.B. (2), X. 594	10 32 24·86	63 59 22·8	,, ,, ,, ,,

A proper motion of +0ˢ·0077 in R.A. has been applied to star *a*, deduced from comparison with Lalande and Weisse's Bessel.

Royal Observatory, Greenwich:
1898 *Sept.* 27.

Observations of Comet 1898 (*Coddington, June* 11) *made at Sydney Observatory.*

(Communicated by H. C. Russell, C.M.G., F.R.S., Government Astronomer.)

1898.	Sydney M.T. h m s	Δ R.A. m s	Δ N.P.D. ′ ″	Cp.	Obs.	R.A. app. h m s	log. p. Δ	N.P.D. app. ° ′ ″	log. p. Δ	Red. ad. l. app. s	Red. dec. app. ″	*
June 16	9 15 52	−1 34·14	+7 20·6	5	S.	16 10 28·11	9·253$_n$	117 54 57·4	0·029	+4·24	+13·5	1
23	8 47 30	+0 22·46	−0 27·4	8	S.	15 45 42·26	9·110$_n$	122 7 37·5	9·528	+4·29	+17·1	2
23	9 38 57	*			S.	15 45 34·45		122 8 53·7	9·372			
24	8 44 10	+0 38·98	−7 33·0	8	S.	15 42 7·91	9·077$_n$	122 41 43·7	9·373	+4·28	+17·6	3
24	9 31 27	*			S.	15 42 0·08		122 42 49·7	9·172			
27	9 9 5	*			L.	15 31 24·36		124 21 37 6	9·018$_n$			
July 4	9 30 14	−0 11·10	+2 47·8	3	S.	15 7 17·73	9·286	127 51 3·6	9·617$_n$	+4·15	+22·1	4
5	8 10 30	*			S.	15 4 11·64		128 16 43·1	9·848$_n$			
6	8 3 21	*			S.	15 0 58·15		128 43 8 5	9·888$_n$			
7	7 56 15	*			S.	14 57 47·71		129 8 56·9	9·923$_n$			

Observer : L.=H. A. Lenehan. S.=R. P. Sellors.

* Observed on the meridian with transit circle.

Mean Places of Comparison Stars for 1898·0.

*	R.A. h m s	N.P.D. ° ′ ″	Authority.
1	16 11 58·01	117 47 23·3	St. 8858. Cord. G.C. 22077. Yarnall$_3$ 6348
2	15 45 15·51	122 7 47·8	Cord. Z.C. 15^h 3084
3	15 41 24·65	122 48 59·1	Cord. G.C. 21386. Wash. Z. (1846) 25·2
4	15 7 24·68	127 47 53·7	Sydney Mer. Obs. 1898

Sydney Observatory:
1898 *July* 12.

Ephemeris for Physical Observations of

(*Continued from*

Greenwich Noon. 1898.	P.	L−O.	B.	A−L.	*B.*	Q.	E.
	°	°	°	°	°	°	°
Nov. 12	353·66	217·42	+15·90	−34·88	+ 1·19	283·39	37·43
14	354·05	218·04	16·05	34·61	1·61	283·51	37·02
16	354·41	218·60	16·17	34·28	2·03	283·62	36·58
18	354·76	219·12	16·27	33·91	2·45	283·71	36·10
20	355·08	219·60	16·35	33·50	2·87	283·77	35·58
22	355·36	220·04	+16·42	−33·06	+ 3·28	283·81	35·03
24	355·62	220·44	16·47	32·58	3·69	283·84	34·43
26	355·86	220·81	16·50	32·07	4·10	283·84	33·81
28	356·07	221·14	16·53	31·52	4·50	283·81	33·14
30	356·25	221·42	16·54	30·93	4·90	283·76	32·42
Dec. 2	356·40	221·66	+16·53	−30·29	+ 5·30	283·68	31·69
4	356·53	221·86	16·50	29·62	5·70	283·55	30·90
6	356·62	222·00	16·46	28·88	6·10	283·39	30·07
8	356·68	222·09	16·40	28·10	6·50	283·19	29·19
10	356·70	222·14	16·31	27·28	6·89	282·95	28·26
12	356·69	222·12	+16·20	−26·39	+ 7·28	282·68	27·28
14	356·64	222·05	16·08	25·45	7·67	282·35	26·26
16	356·56	221·92	15·94	24·45	8·05	281·99	25·17
18	356·44	221·75	15·78	23·41	8·43	281·56	24·03
20	356·28	221·52	15 61	22·32	8 81	281·06	22·84
22	356·09	221·23	+15·42	−21·16	+ 9·18	280·47	21·59
24	355·87	220·89	15·22	19·95	9·55	279·78	20·29
26	355·62	220·50	15·00	18·70	9·92	278·99	18·95
28	355·32	220·05	14·76	17·39	10·29	278·12	17·55
30	354·98	219·55	14·51	16·02	10·65	277·04	16·12
1899. Jan. 1	354 62	219·02	+14·25	−14·63	+11·01	275·74	14·63
3	354·23	218·44	13·97	13·18	11·37	274·14	13·12
5	353·81	217·82	13·68	11·72	11·72	272·28	11·57
7	353·37	217·17	13·39	10·18	12·07	269·77	10·01
9	352·92	216·50	13·09	8·64	12·41	266·45	8·43
11	352·45	215·80	+12·77	− 7·07	+12·75	261·70	6·87
13	351·94	215·07	12·45	5·47	13·09	254·29	5·34
15	351·44	214·32	12·13	3·85	13·43	241·71	3·95
17	350·94	213·57	+11·80	− 2·23	+13·76	218·40	2·91

Mars, 1898–99. By A. C. D. Crommelin.

page 468.)

Greenwich Noon. 1898.	Light Time. m	Appar. Diam. "	Defect of Illumination. q "	Central Meridian. ω_0 °	Passage of Zero Meridian. h m	h m
Nov. 12	8·10	9·85	1·01	115·00	16 46	16 8
14	7·98	10·00	1·01	96·20	18 4	17 25
16	7·86	10·16	1·00	77·45	19 20	18 42
18	7·74	10·32	0·99	58·74	20 37	19 58
20	7·62	10·49	0·98	40·08	21 54	21 15
22	7·49	10·66	0·97	21·45	23 10	22 32
24	7·37	10·83	0·95	2·87	...	23 48
26	7·25	11·01	0·93	344·31	1 4	0 26
28	7·13	11·19	0·91	325·79	2 20	1 42
30	7·01	11·38	0·89	307·33	3 36	2 58
Dec. 2	6·90	11·57	0·86	288·90	4 52	4 14
4	6·79	11·76	0·83	270·51	6 7	5 30
6	6·68	11·95	0·80	252·18	7 23	6 45
8	6·57	12·15	0·77	233·90	8 38	8 1
10	6·47	12·34	0·73	215·66	9 53	9 16
12	6·37	12·54	0·69	197·49	11 7	10 30
14	6·27	12·73	0·65	179·37	12 21	11 44
16	6·18	12·92	0·61	161·30	13 35	12 58
18	6·09	13·11	0·57	143·28	14 49	14 12
20	6·01	13·30	0·52	125·31	16 3	15 26
22	5·93	13·48	0·47	107·40	17 16	16 40
24	5·85	13·65	0·42	89·55	18 29	17 53
26	5·78	13·81	0·37	71·74	19 42	19 6
28	5·71	13·97	0·32	53·99	20 55	20 19
30	5·65	14·12	0·27	36·29	22 8	21 32
1899.						22 44
Jan. 1	5·60	14·26	0·23	18·61	23 20	
3	5·55	14·38	0·19	0·99	...	23 56
5	5·51	14·49	0·15	343·40	1 8	0 32
7	5·48	14·58	0·11	325·85	2 20	1 44
9	5·45	14·65	0·08	308·31	3 32	2 56
11	5·43	14·70	0·06	290·80	4 44	4 8
13	5·42	14·74	0·04	273·31	5 56	5 20
15	5·41	14·76	0·02	255·85	7 7	6 32
17	5·41	14·75	0·01	238·38	8 18	7 43

Greenwich Noon.	P.	L−O.	B.	A−L.	B.	Q.	E.
1899.	°	°	°	°	°	°	°
Jan. 19	350·44	212·81	+11·48	− 0·60	+14·09	182·43	2·67
21	349·94	212·07	+11·18	+ 1·01	+14·41	152·54	3·39
23	349·44	211·33	10·88	2·62	14·73	135·80	4·65
25	348·94	210·61	10·59	4·21	15·05	126·53	6·09
27	348·47	209·91	10·32	5·79	15·37	120·73	7·61
29	348·01	209·23	10·05	7·35	15·68	116·85	9·13
31	347·58	208·58	+ 9·80	+ 8·88	+15·98	113·99	10·67
Feb. 2	347·17	207·97	9·58	10·37	16·28	111·74	12·16
4	346·79	207·40	9·38	11·82	16·58	109·97	13·62
6	346·44	206·86	9·19	13·24	16·87	108·55	15·04
8	346·11	206·36	9·03	14·63	17·16	107·39	16·42
10	345·81	205·92	+ 8·89	+15·95	+17·44	106·37	17·77
12	345·55	205·52	8·78	17·23	17·72	105·46	19·03
14	345·32	205·17	8·68	18·47	18·00	104·66	20·28
16	345·13	204·87	8·60	19·66	18·27	103·95	21·46
18	344·96	204·61	8·55	20·81	18·54	103·34	22·59
20	344·83	204·41	+ 8·53	+21·90	+18·80	102·84	23·65
22	344·73	204·25	8·55	22·96	19·06	102·43	24·69
24	344·67	204·13	8·58	23·98	19·31	102·07	25·66
26	344·63	204·06	8·61	24·95	19·56	101·75	26·58
28	344·63	204·04	8·66	25·87	19·81	101·47	27·45
Mar. 2	344·66	204·07	+ 8·73	+26·74	+20·05	101·24	28·23
4	344·72	204·14	8·82	27·57	20·29	101·04	29·00
6	344·79	204·25	8·93	28·36	20·52	100·89	29·73
8	344·90	204·40	9·06	29·12	20·74	100·77	30·41
10	345·04	204·60	9·22	29·83	20·96	100·68	31·06
12	345·20	204·83	+ 9·39	+30·51	+21·17	100·62	31·66
14	345·38	205·09	9·58	31·16	21·38	100·59	32·22
16	345·59	205·39	9·78	31·78	21·58	100·59	32·74
18	345·82	205·73	9·99	32·36	21·78	100·61	33·23
20	346·08	206·10	10·20	32·91	21·98	100·65	33·67
22	346·35	206·50	+10·43	+33·44	+22·17	100·71	34·08
24	346·64	206·93	10·67	33·93	22·35	100·80	34·46
26	346·95	207·39	10·93	34·39	22·53	100·90	34·81
28	347·29	207·88	11·20	34·82	22·70	101·02	35·14
30	347·64	208·41	11·47	35·22	22·87	101·15	35·43
Apr. 1	348·01	208·96	+11·75	+35·60	+23·03	101·30	35·70
3	348·40	209·53	+12·05	+35·96	+23·19	101·46	35·94

Greenwich Noon. 1899.	Light Time. m	Appar. Diam. "	Defect of Illumination. q "	Central Meridian. ω_o °	Passage of Zero Meridian. h m	h m
Jan. 19	5·42	14·72	0·01	220·92	9 29	8 54
21	5·44	14·67	0·01	203·44	10 41	10 5
23	5·47	14·60	0·02	185·96	11 53	11 17
25	5·50	14·52	0·04	168·46	13 4	12 28
27	5·54	14·42	0·06	150·93	14 16	13 40
29	5·58	14·30	0·09	133·38	15 28	14 52
31	5·63	14·17	0·12	115·81	16 41	16 4
Feb. 2	5·69	14·02	0·16	98·19	17 54	17 17
4	5·76	13·86	0·20	80·52	19 6	18 30
6	5·83	13·69	0·24	62·83	20 19	19 42
8	5·91	13·50	0·28	45·09	21 32	20 55
10	6·00	13·31	0·32	27·30	22 45	22 8
12	6·09	13·11	0·36	9·46	23 58	23 21
14	6·18	12·91	0·40	351·57	0 35	...
16	6·28	12·70	0·44	333·63	1 48	1 11
18	6·39	12·49	0·48	315·65	3 2	2 25
20	6·50	12·27	0·52	297·61	4 16	3 39
22	6·62	12·06	0·55	279·52	5 30	4 53
24	6·74	11·85	0·58	261·40	6 44	6 7
26	6·86	11·64	0·61	243·22	7 59	7 21
28	6·98	11·43	0·64	225·00	9 14	8 36
Mar. 2	7·11	11·22	0·67	206·72	10 29	9 51
4	7·24	11·02	0·69	188·40	11 44	11 6
6	7·38	10·82	0·71	170·04	12 59	12 21
8	7·52	10·62	0·73	151·64	14 15	13 37
10	7·66	10·42	0·75	133·19	15 31	14 53
12	7·80	10·23	0·76	114·71	16 47	16 9
14	7·94	10·05	0·77	96·20	18 3	17 25
16	8·08	9·87	0·78	77·65	19 19	18 41
18	8·23	9·69	0·79	59·06	20 36	19 57
20	8·38	9·52	0·80	40·44	21 52	21 14
22	8·53	9·35	0·80	21·78	23 9	22 31
24	8·68	9·19	0·81	3·10	...	23 47
26	8·84	9·03	0·81	344·39	1 4	0 26
28	8·99	8·88	0·81	325·65	2 21	1 42
30	9·15	8·73	0·81	306·86	3 38	2 59
April 1	9·30	8·59	0·81	288·06	4 55	4 16
3	9·46	8·45	0·81	269·23	6 12	5 33

Greenwich Noon.	P.	L−O.	B.	A−L.	*B.*	Q.	E.
1899.	°	°	°	°	°	°	°
April 5	348·81	210·13	+12·35	+36·29	+23·35	101·63	36·16
7	349·22	210·75	12·66	36·60	23·50	101·81	36·35
9	349·65	211·40	12·97	36·89	23·64	102·00	36·52
11	350·10	212·07	+13·28	+37·16	+23·77	102·21	36·67
13	350·56	212·77	13·60	37·40	23·90	102·43	36·80
15	351·03	213·48	13·92	37·63	24·02	102·65	36·91
17	351·52	214·21	14·24	37·85	24·13	102·88	37·00
19	352·02	214·96	14·57	38·06	24·24	103·11	37·07
21	352·53	215·74	+14·91	+38·25	+24·34	103·34	37·13
23	353·06	216·53	15·25	38·42	24·44	103·58	37·17
25	353·60	217·34	15·59	38·57	24·53	103·82	37·19
27	354·14	218·17	15·92	38·69	24·62	104·07	37·20
29	354·70	219·02	16·26	38·79	24·71	104·32	37·20
May 1	355·27	219·88	+16·60	+38·89	+24·79	104·57	37·18
3	355·84	220·76	16·94	38·97	24·86	104·82	37·15
5	356·42	221·65	17·28	39·05	24·92	105·08	37·11
7	357·02	222·56	17·62	39·10	24·98	105·34	37·06
9	357·62	223·49	17·95	39·14	25·03	105·60	37·00
11	358·22	224·43	+18·28	+39·17	+25·08	105·86	36·92
13	358·84	225·39	18·61	39·18	25·12	106·13	36·83
15	359·47	226·36	18·94	39·18	25·15	106·40	36·74
17	0·10	227·35	19·27	39·16	25·17	106·66	36·63
19	0·74	228·35	19·59	39·14	25·19	106·92	36·52
21	1·38	229·36	+19·90	+39·11	+25·20	107·17	36·39
23	2·03	230·39	20·21	39·06	25·21	107·42	36·26
25	2·69	231·43	20·52	38·99	25·21	107·67	36·12
27	3·35	232·49	20·82	38·91	25·21	107·92	35·98
29	4·02	233·56	21·12	38·82	25·20	108·17	35·83
31	4·69	234·64	+21·42	+38·71	+25·18	108·41	35·66
June 2	5·37	235·73	21·71	38·60	25·15	108·65	35·49
4	6·05	236·83	21·99	38·48	25·11	108·88	35·32
6	6·74	237·95	22·26	38·34	25·07	109·11	35·13
8	7·43	239·09	22·53	38·18	25·03	109·33	34·94
10	8·12	240·24	+22·79	+38·02	+24·98	109·54	34·75
12	8·81	241·40	23·04	37·84	24·92	109·75	34·55
14	9·51	242·57	23·28	37·66	24·86	109·95	34·34
16	10·22	243·76	23·52	37·45	24·79	110·15	34·13
18	10·92	244·95	+23·75	+37·24	+24·71	110·35	33·91

Greenwich Noon. 1899.	Light Time. m	Appar. Diam. "	Defect of Illumination. q "	Central Meridian. ω_0 °	Passage of Zero Meridian. h m	h m
April 5	9·61	8·31	0·80	250·38	7 29	6 50
7	9·76	8·18	0·80	231·51	8 47	8 8
9	9·92	8·05	0·79	212·60	10 5	9 26
11	10·07	7·92	0·79	193·68	11 23	10 44
13	10·23	7·80	0·78	174·73	12 41	12 2
15	10·38	7·68	0·78	155·77	13 59	13 20
17	10·54	7·57	0·77	136·78	15 17	14 38
19	10·70	7·46	0·76	117·78	16 35	15 56
21	10·85	7·35	0·75	98·74	17 53	17 14
23	11·01	7·25	0·74	79·70	19 11	18 32
25	11·16	7·15	0·73	60·64	20 30	19 50
27	11·32	7·05	0·72	41·55	21 48	21 9
29	11·47	6·96	0·71	22·45	22 7	22 27
May 1	11·62	6·87	0·70	3·33	...	23 46
3	11·78	6·78	0·69	344·20	1 5	0 26
5	11·93	6·69	0·68	325·06	2 23	1 44
7	12·08	6·61	0·67	305·89	3 42	3 2
9	12·23	6·53	0·66	286·71	5 1	4 21
11	12·38	6·45	0·65	267·52	6 20	5 40
13	12·52	6·37	0·64	248·31	7 39	6 59
15	12·67	6·30	0·63	229·09	8 58	8 18
17	12·81	6·23	0·62	209·85	10 17	9 37
19	12·96	6·16	0·60	190·60	11 36	10 56
21	13·11	6·09	0·59	171·33	12 56	12 16
23	13·25	6·02	0·58	152·05	14 15	13 36
25	13·39	5·96	0·57	132·76	15 34	14 55
27	13·53	5·90	0·56	113·46	16 53	16 14
29	13·67	5·84	0·55	94·14	18 12	17 33
31	13·81	5·78	0·54	74·81	19 31	18 52
June 2	13·95	5·72	0·53	55·47	20 51	20 11
4	14·08	5·67	0·52	36·12	22 11	21 31
6	14·21	5·62	0·51	16·75	23 31	22 51
8	14·35	5·56	0·50	357·36	0 11	...
10	14·48	5·51	0·49	337·96	1 30	0 51
12	14·61	5·46	0·48	318·55	2 50	2 10
14	14·74	5·41	0·47	299·14	4 10	3 30
16	14·87	5·36	0·46	279·70	5 30	4 50
18	15·00	5·32	0·45	260·26	6 50	6 10

Greenwich Noon.	P.	L−O.	B.	Λ−L.	*B.*	Q.	E.
1899.	°	°	°	°	°	°	°
June 20	11·62	246·15	+23·96	+37·04	+24·63	110·54	33·69
22	12·33	247·36	24·17	36·81	24·54	110·72	33·46
24	13·04	248·59	24·38	36·57	24·44	110·90	33·23
26	13·75	249·82	24·57	36·32	24·33	111·07	33·00
28	14·46	251·07	24·75	36·06	24·22	111·23	32·76
30	15·17	252·32	+24·92	+35·79	+24·11	111·39	32·52
July 2	15·87	253·58	25·08	35·52	23·99	111·54	32·27
4	16·57	254·85	25·23	35·23	23·86	111·69	32·02
6	17·27	256·13	25·37	34·94	23·72	111·83	31·76
8	17·97	257·42	25·49	34·64	23·58	111·96	31·50
10	18·67	258 72	+25·60	+34·33	+23·43	112·08	31·24
12	19·37	260·04	25·71	34·00	23·28	112·19	30·98
14	20·07	261·37	25·81	33·66	23·12	112·29	30·71
16	20·76	262·70	+25·90	+33·32	+22·95	112·38	30·44

The constants are the same as those employed in the first portion of the ephemeris.

L−O+180°, Λ−O+180° are the longitudes of the Earth and Sun referred to the plane of *Mars*' equator and reckoned from O, the point of the vernal equinox of *Mars*' northern hemisphere ; thus Λ−L is the angle between the meridians of *Mars* which are central to the Earth and to the Sun ; B, *B* are the latitudes of the Earth and Sun reckoned from the plane of *Mars*'

Greenwich Noon.	Light Time.	Appar. Diam.	Defect of Illumination.	Central Meridian.	Passage of Zero Meridian.	
			q	ω_0		
1899.	m	"	"	°	h m	h m
June 20	15·12	5·28	0·44	240·82	8 10	7 30
22	15·24	5·24	0·43	221·36	9 30	8 50
24	15·36	5·20	0·42	201·89	10 51	10 10
26	15·48	5·16	0·42	182·41	12 11	11 31
28	15·60	5·12	0·41	162·92	13 31	12 51
30	15·72	5·08	0·40	143·42	14 51	14 11
July 2	15·84	5·04	0·39	123·92	16 11	15 31
4	15·95	5·00	0·38	104·40	17 31	16 51
6	16·06	4·97	0·37	84·88	18 51	18 11
8	16·17	4·93	0·37	65·35	20 11	19 31
10	16·28	4·90	0·36	45·81	21 32	20 51
12	16 39	4·87	0·35	26·24	22 52	22 12
14	16·50	4·84	0·34	6·67	...	23 32
16	16·60	4·81	0·33	347·10	0 53	0 13
						1 34

equator, Q the position angle of the greatest defect of illumination, q the amount of the greatest defect of illumination, E the areocentric angle between the Earth and Sun.

The spring equinox of Mars' northern hemisphere occurs 1898 November $6^d{\cdot}3$, and the summer solstice 1899 May $24^d{\cdot}2$.

Benvenue, Ulundi Road, Blackheath, S.E.:
1898 *September* 28.

Erratum in Mr. Merfield's *paper*, vol. lviii. p. 457, second term of right-hand member of last equation :

for $[7{\cdot}1638 - 10]\left(\frac{d^2d}{dt^2} + \frac{d\mu}{dt}\right)$

read $[7{\cdot}1638_n - 10]\left(\frac{d^2d}{dt^2} + \frac{d\mu}{dt}\right)\sin\alpha.$

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——— Pulgaon, Captain E. H. Hills and H. F. Newall ..... [43]

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON

THE SOLAR CORONA

Of 1898 Jan 22nd.

Photographed at Pulgaon, Central India, by Captain E. H. Hills, R.E.
Dallmeyer Photoheliograph Lens, 5 in. diameter.—Equivalent focus, 15 ft.
Exposure 8 seconds.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Appendix to Vol. LVIII.

[*From Proc. Roy. Soc.*]

"Report on the Expedition to Sahdol, Rewah State, Central India, to observe the Total Solar Eclipse of 1898 January 22." By W. H. M. Christie, C.B., M.A., F.R.S., Astronomer Royal, and Professor H. H. Turner, M.A., F.R.S. Received May 25, 1898.

The Report is presented in three parts.
Part I is a joint Report by the two observers.
Part II is a separate Report by the Astronomer Royal; and
Part III is a separate Report by Professor Turner.

Part I.

1. This expedition was organised by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee.

The Government of India made excellent arrangements for the party, and the Surveyor-General of India with the staff of his Department rendered great service in selecting a site, clearing the ground, establishing a camp, erecting the instruments, and in giving valuable assistance in the observations, for all of which the observers desire to tender their thanks.

The observers are also indebted to the Great Indian Peninsular Railway, the Bengal and Nagpur Railway, and the East Indian Railway for great liberality in granting facilities and in making special arrangements for the safe conveyance of their instruments from Bombay to Sahdol.

Personnel.—The following persons took part in the expedition:—

W. M. Christie, M.A., F.R.S., Astronomer Royal.

H. H. Turner, M.A., F.R.S., Savilian Professor of Astronomy at Oxford.

Harold A. H. Christie, who gave the exposures throughout the eclipse for the Astronomer Royal.

It was originally proposed that Dr. A. A. Common, F.R.S., should also take part in this expedition, but he ultimately found that he was unable to do so, and Dr. Copeland, Astronomer Royal for Scotland, was invited by the J.P.E. Committee to go in his place. Dr. Copeland preferred, however, not to join any of the three other expeditions, but to establish himself independently.

3. *Itinerary.*—The observers left Marseilles in the Peninsular and Oriental steamship "Ballaarat" (R.M.S.), on Thursday morning, December 16, 1897, their instruments having been put on board this vessel in London ten days earlier. They arrived at Bombay on Monday morning, January 3, 1898, the weather during the voyage being excellent. After a few days spent in landing the instruments and arranging for their journey to Sahdol, they left Bombay on Friday evening, January 7, travelling direct to Sahdol by special arrangements courteously made by the G.I.P., East Indian, and Bengal and Nagpur Railways, and arrived at Sahdol in the early morning of Sunday, January 9.

4. *Selection of a Station.*—The J.P.E. Committee originally proposed for this expedition a station south of Poona, either near Karad on the S. Maratha Railway or near Jeur on the G.I.P. Railway, other expeditions occupying stations near Viziadrug on the coast, and Pulgaon on the Nagpur branch of the G.I.P. Railway.

The Surveyor-General of India having offered to give every assistance to the expeditions, appointed Major Burrard, R.E., to make all necessary arrangements, including the determination of exact local time and of the longitude and latitude of the station. Major Burrard selected Karad, in the Satara district, as the best tation. Owing, however, to the outbreak of plague at that place, and its prevalence in the Bombay Presidency, it was finally decided, on the advice of the Bombay Government, to abandon this choice and to occupy a station at Sahdol, on the railway to the east of Pulgaon, connecting Katni and Bilaspur. As this site was in dense jungle, it was necessary to clear a considerable space for the camp, part of which was to be occupied by a party under Mr. Michie Smith, Government Astronomer at Madras. This clearing, the establishment of the camp, and the erection of piers and huts for the instruments and of a dark room for photography, were all admirably carried out by Major Burrard, R.E., and his assistant, Lieutenant Crosthwait, R.E., before the arrival of the observers, who thus found everything ready for the setting up of their instruments.

5. *Position of Station.*—The observing station was about three-quarters of a mile from the railway station, on the south side of the line. The position of the centre of the pier on which the cœlostat used by the Astronomer Royal was mounted is—

Longitude 81° 21′ 33″ E. = $5^h\ 25^m\ 26^s{\cdot}2$ E.
Latitude 23° 16′ 45·3″.
Height above mean sea level 1502·4 feet.

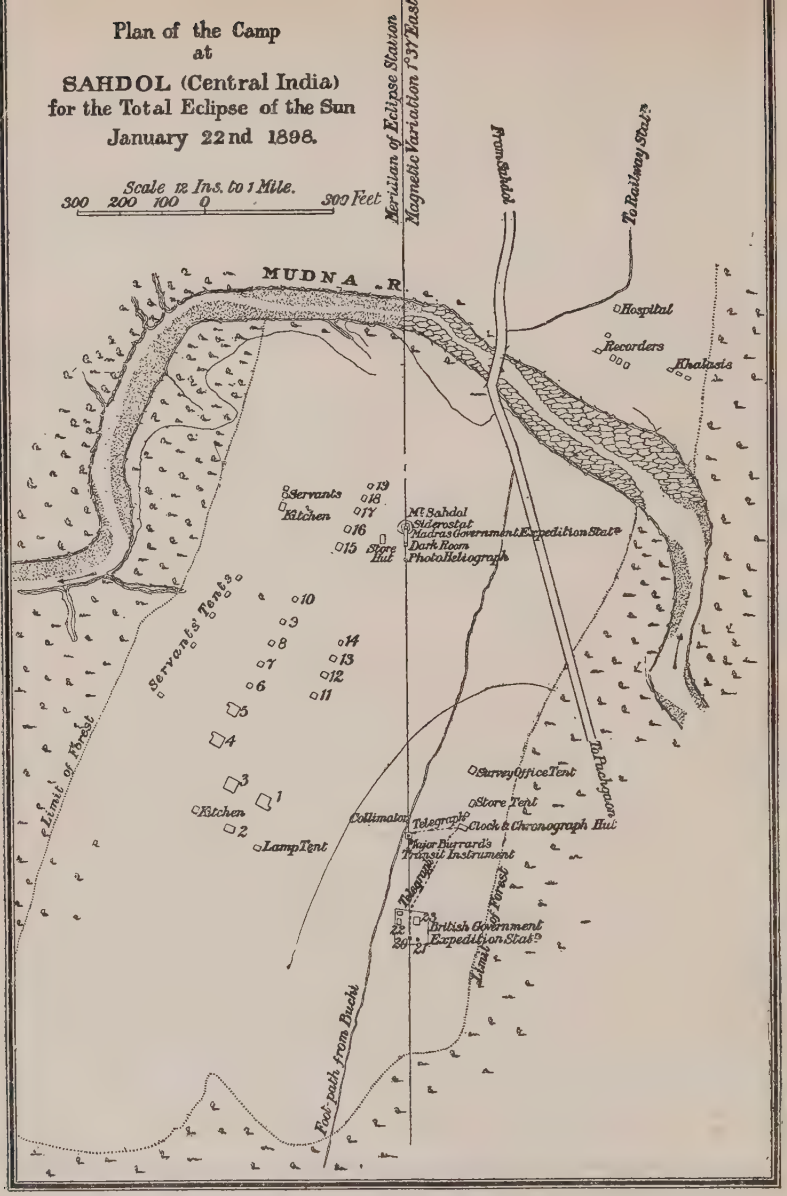
This position was determined after the eclipse by Major Burrard, R.E., by accurate triangulation, connecting the site with the principal triangulation of the Survey of India.

Professor Turner's cœlostat was 20 feet due east of this, and the transit instrument (used by Major Burrard in his time determinations) 240 feet due north of it.

This spot is 4 miles towards the south-east from the central line as shown in the 'Nautical Almanac' and 'American Ephemeris,' $3\frac{1}{4}$ miles from the line as shown in the 'Connaissance des Temps,' and 2 miles from the line as shown in the 'Berliner Jahrbuch.' It may be remarked that the data for predicting the four contacts given in the 'Nautical Almanac Circular No. 16' were found insufficient, the nearest points for which approximate formulæ were given being in longitude 79° (Nagpur) at a considerable distance from the central line, and in longitude 83° (south of Benares), too far away to give accurate predictions. [See Professor Turner's separate Report.]

6. *The Camp.*—The general arrangements of the camp (see next page), which consisted of more than fifty tents and huts, were, as already mentioned, admirably carried out by Major Burrard, R.E., it being necessary to clear a considerable space (about 700 by 300 yards) in the jungle by burning and felling trees, in order to set up the numerous tents of the living camp at some distance from the observing huts. On part of this clearing the Government Astronomer at Madras (Mr. Michie Smith) and his assistants erected their camp and instruments, and Major Burrard rendered considerable assistance to this party. There were also several tents for occupation by distinguished officers of the Survey, and we had the pleasure of seeing at the camp on the day of the eclipse the Surveyor-General (General Strahan, R.E.), General Woodthorpe, R.E., Colonel Sir T. Holditch, R.E., and other officers, and for a few days preceding the eclipse Colonel Gore, R.E., who left us for the Pulgaon Camp on January 19.

7. *Meteorological Conditions.*—From valuable information collected by Mr. Eliot, Meteorological Reporter to the Government of India, it appeared that the chances of fine weather were practically the same all along the line of totality, there being very little risk of cloud, though some chance of dust interfering with the definition. The thickly wooded country round Sahdol seemed well adapted for protection from the danger of dust, and during the days near the eclipse the ground near the instruments was covered with straw and watered in the morning to prevent excessive heating of the air in the



REFERENCE.

1. Mr. W. H. M. Christie, C.B., F.R.S. / Master Harold Christie.
2. Lieut. H. L. Crosthwait, R.E.
3. Mess.
4. Professor H. H. Turner, F.R.S.
5. Major S. G. Burrard, R.E.
6. Mr. C. H. McA'Fee.
7. Mr. R. George.
8. Captain E. D. Bullen, R.E.
9. Colonel Sir T. H. Holditch, K.C.I.E., C.B., R.E.
10. Captain J. A. Dealy, R.E.
11. General C. Strahan, R.E. / Colonel St. G. C. Gore, R.E.
12. General R. G. Woodthorpe, C.B., R.E.
13. Mr. C. Michie Smith.
14. Captain W. Ewbank, R.E.
15. Mr. A. H. Campbell, I.C.S. / Surgeon-Major J. L. Van Geyzel, I.M.S.
16. Madras Mess.
17. Doctor J. W. Evans.
18. Mr. F. W. Lawrence. / Mr. A. F. N. Moos.
19. Mr. R. Ll. Jones. / Mr. H. Kelsall Slater.
20. Mr. Christie's cœlostat — Lat. 23° 16′ 45″·3 N. / Long. 81° 21′ 33″·0 E. / Height 1502·4 feet.
21. Professor Turner's cœlostat.
22. Dark room.
23. Instrument tent.

path of the rays from the sun to the cœlostats, which were placed at a height of only 2 feet 8 inches from the ground.

The character of the weather was practically uniform during our stay at Sahdol. At night the minimum temperature was about 32° up to January 20, afterwards a little warmer (not falling below 39°, on January 23 and 24). At about 7.30 A.M., soon after sunrise, the temperature began to rise rapidly, attaining a maximum of about 80° at about 2 P.M., and remaining near this point from noon till about 4.30 P.M., when a fall nearly as sudden as the rise began. The air was nearly saturated with moisture at night and very dry in the daytime. There was heavy hoar frost at night.

These conditions seriously limited the time available for photography, which could only be carried on conveniently during the hot part of the day, say from 10 A.M. to 6 or 7 P.M., as there was no ready means of warming the water in the dark room.

The first clouds seen since the party landed in India were light fleecy clouds in the evening of Wednesday, January 19, and more appeared in the early mornings of January 20 and January 21, dispersing in each case between 10 and 11 A.M. The day of the eclipse was perfectly cloudless throughout, and the definition good.

[For detailed readings of thermometers and barometer, see separate Report by Professor Turner.]

8. *Instruments, &c.* [See separate Reports of the observers.]

9. *Huts.*—The chances of rain being so small, waterproof huts were not considered necessary, and the instruments were protected by rush thatchings laid on a framework of bamboo, which could be readily removed as required.

10. *Assistance.*—The observers were assisted in the exposures as below:—

The Astronomer Royal—	
Mr. McA'Fee.....	Recorded times of exposure.
Mr. Harold Christie	Exposed at objective.
Vishnoo Babaji Garud....	Handed plates.
Venayek Narayan	Received plates.
Professor Turner—	
Dondu Venayek.....	Exposed at objective.
Tukaran Hanmant.....	Handed plates.
Shankar Devidas	Received plates.
Also	
Govind Balwant Joshi.... } Narayan Vishnoo Apte.... }	Counted seconds aloud.

A few seconds before totality, as shown by the diminishing crescent of the sun, Professor Turner was to call "Get ready"; at totality to call sharply (the monosyllable "Tup" was used). The first time-

keeper immediately started the stop-watch and proceeded to count aloud "one, two, three," &c., up to sixty, when the second time-keeper took up the counting, "one, two, three," &c. By having two timekeepers, opportunity was given to both to see the eclipse.

The operations were rehearsed on every day of the week preceding the eclipse, at the time of totality, and on two days also at dusk, with lamps.

A photographic hut with a supply of chemicals was supplied from the Calcutta office of the Surveyor-General's Department, and Mr. George, of that department, was told off to assist in the photographic work. He developed some of the photographs taken by the Astronomer Royal during the partial phases.

11. *The Day of the Eclipse.*—Perfectly clear throughout. The morning was spent in final preparations. The first contact occurred at 0 hr. 13·3 mins. local mean time, and the Astronomer Royal proceeded to take nine photographs of the partial phase, the first being exposed at 0 hr. 14·6 mins., and the last at 1 hr. 22·2 mins. Totality commenced at 1 hr. 41·1 mins., and lasted about 105 seconds, during which time the programmes detailed below were successfully carried out. Nine more partial phase photographs were taken between 1 hr. 59·4 mins. and 2 hrs. 59·2 mins. The fourth contact was at 3 hrs. 1·6 mins. (see accurate times below).

There was a good deal of light during totality, and lamps were not in any way needed. The temperature fell 4·5° between first and second contacts, and another 3·5° between second contact and 2 hrs. It had practically returned to its normal value by the fourth contact (see accurate readings below). But the fall of temperature did not nearly represent the sensation of chill. At 1.15, when the air felt distinctly chilly, the temperature had only fallen 2°.

There was no appreciable "shadow" effect at totality, nor was any such effect noticed by two observers (General Woodthorpe, R.E., and Colonel Sir T. Holditch, R.E.) from the top of a hill a few miles away, close to the central line. These observers did, however, notice the well known "shadow bands" on the table they had prepared for sketching, without having previously heard of these bands in any way.

We had not many opportunities of observing the behaviour of animals. Kites which had been circling round the camp flew off to the surrounding trees some minutes before totality, and about the same time we heard cries from the village of Sahdol. We were told by another observer (Professor E. G. Hill, of Allahabad) that at Buxar he had noticed a herd of goats get into line and march homewards; that two mongooses in a hole in a bank had seemed very much frightened; that squirrels were silent during totality, and that a kingfisher began catching fish.

Part II.—Separate Report by Mr. W. H. M. Christie.

The programme of observation was composed of two distinct parts—(1) Photographs of the corona on a large scale during totality; (2) photographs of the partial phase before and after totality for determination of the position of the moon relatively to the sun.

The instrument used in both cases was the photographic telescope by Grubb, with object-glass of 9 inches aperture and 8 ft. 6 in. focal length (presented to the Royal Observatory by Sir Henry Thompson), to which a concave compound lens by Dallmeyer, of 3 inches diameter and 12 inches focus, had been fitted as a secondary magnifier, placed a short distance within the focus. This combination gave an image of the sun 4 inches in diameter, and a field (for full pencils) of nearly 10 inches diameter, so that the corona to a distance of one and a half radii from the Sun's limb would be included in the field. A cœlostat, specially designed by Dr. Common, carrying a plane silver-on-glass mirror of 16 inches diameter, made by him, was employed to reflect the rays into the Thompson coronagraph, which was firmly mounted on two brick piers, so as to point to the mirror at an angle of depression of about 10°, and to be placed in an azimuth of about 17° north of west for the day of the eclipse. The camera was furnished with eight plateholders, taking 12×10 in. plates, seven being reserved for use during totality, and the eighth fitted with a Thornton-Pickard instantaneous focal-plane shutter, to take photographs on $8\frac{1}{2} \times 6\frac{1}{2}$ in. plates during the partial phases, for determination of the moon's position.

The seven slides for photographs of the corona during totality were exposed as below, the exposures being given with a screen held

No.	Exposure.			Plate.	Developer.
	Beginning.	End.	Duration.		
	Secs.	Secs.	Secs.		
1	6	7	1	Ilford ordinary.....	Hydroquinone dilute.
2	12	17	5	Ilford rapid.....	,, ,,
3	24	34	10	,, ,, (backed).....	,, ,,
4	40	60	20	Rocket (backed).....	,, ,,
5	67	75	8	,, ...	Eikonogen.
6	81	82	$\frac{2}{3}$	Ilford ordinary	Hydroquinone dilute.
7	89	91	2	Gazelle (dry collodion)....	,, ,,

in front of the object-glass by my son Harold, and the times, reckoned from the commencement of totality (2nd contact), being recorded by Mr. McA'Fee, of the Indian Survey Department.

It had been intended to use Hill-Norris dry collodion "Gazelle" plates for three of the slides (the fineness of grain as compared with gelatine plates giving them a marked advantage), but from trials made before the eclipse it was found that these plates were for some reason untrustworthy. I, however, thought it well to expose one of these plates, but the result is not satisfactory.

The sky was cloudless during the eclipse, and the programme was carried out without a hitch, with the aid of two native assistants of the Survey Department (Mr. V. B. Garud and Mr. V. Narayen), who respectively handed me the slides and received them from me, and there was fifteen seconds to spare before the end of totality, the duration at Sahdol being 1 min. $45\frac{1}{2}$ secs. as observed.

For the partial phase, nine photographs were taken between first and second contacts, and eight between third and fourth contacts, as well as a photograph for orientation (with double exposure) immediately before and after the eclipse. The aperture of the object-glass was reduced to 3 inches for these photographs, as it was found by trials before the eclipse that with the aperture thus reduced the exposure given by the Thornton-Pickard shutter set to its highest speed was satisfactory for the slow plates used (Thomas's lantern plates). The times of exposure were recorded on a chronograph, a key being pressed by me in the left hand at the same instant as the exposure was given by pressing a pneumatic ball in the right hand. The times of the fall of the shutter were also independently recorded by Mr. McA'Fee with a chronometer carefully compared with the transit-clock. All the arrangements for accurate local time, which was of vital importance for this part of the programme, and for determination of the longitude of the station by connection with the principal triangulation of the Survey of India, were most ably carried out by Major Burrard, R.E., and Lieut. Crosthwait, R.E. The position of my instrument, as found by them after the eclipse, was Long. 81° 21′ 33″ = 5^h 25^m $26^s{\cdot}2$ E., Lat. 23° 16′ 45·3″ N. Altitude above sea-level 1502·4 feet.

The coronagraph was carefully focussed before the eclipse by use of the method described in the Report of the Eclipse Expedition to Japan, 1896,* the image of an object (gauze net in the plane of the plate), being photographed by reflection normally from the plane mirror of the cœlostat. A special spare back for the plateholder was prepared with a hole covered with gauze net just above the centre, and one of the 12 × 10 in. plates being cut in two, one half was placed in the lower half of the plateholder and the reflected image photo-

* 'Monthly Notices,' R.A.S., vol. 57, p. 105.

graphed on it at different parts of the field, the source of light being a paraffin lantern. The adjustment to focus was made by moving the secondary magnifier, rings of paper placed between flanges on the adapter carrying the magnifier and its mounting giving the means of doing this with great nicety. By this method, in which the error from imperfect focus is doubled by the double passage of the rays through the telescope, it was found that a displacement of the magnifier through the thickness of a sheet of paper (0·005 inch), representing 1/20,000th part of the focal length, made a sensible difference. The focus was thus obtained with great accuracy, as is evidenced by the sharpness of the image on the photographs taken during the partial phase.

The photographs with exposures of 8 secs., 10 secs., and 20 secs. all show coronal structure up to the edge of the plate, the streamer in the S.W. being particularly bright. A hurried eye estimation made by me during the 20 seconds' exposure gave the extreme extension of this streamer as about two-thirds of the distance of Venus from the Sun's centre, or about $3\frac{1}{2}^\circ$ from the limb. The field being necessarily limited by the diameter of the concave enlarging lens (3 in.), it would be desirable to have one made of larger diameter for future eclipses so as to allow of the use of larger plates.

A comparison of the whole series of photographs indicates a close correspondence between the coronal streamers and the prominences visible, this correspondence being particularly striking in the case of three prominences in the N.W. quadrant from which three coronal rays rise, arching over at a distance of about 7′ from the limb and uniting to form one component of the striking long double ray in that quadrant. Other prominences on the Sun's limb appear also to be associated with extensions of the corona. The form of the corona bore a closer general resemblance to those of 1886 and 1896 as photographed than would have been expected considering that the date of the eclipse was so much nearer the epoch of minimum sun-spots, and in this connection it may be noted that there were three important groups of spots on the Sun about the time of the eclipse, and that a series of magnetic disturbances of moderate amount were recorded at Greenwich just prior to the eclipse, from January 15 to 21 continuously, indicating an unusual state of magnetic activity in close correspondence with the solar activity as evidenced by the Sun spots.

Part III.—Separate Report by Professor Turner.

Instrumental Equipment.

1. *The Camera.*—The double camera used in the Fundium Expedition of 1893 by Sergeant Kearney, and taken out to Japan in 1896 without result. The tube is of wood, 6 feet long and 14 × 7 inches in section, divided by a partition into two tubes of 7 × 7 inches section. In one of these is placed the "Abney"* lens of 4-inch aperture and 62-inch focal length, giving an image of the sun 0·57 inch in diameter; in the other the photoheliograph objective No. 2 (used in *Transit of Venus* expeditions), of 4-inch aperture and 5-feet focal length, with a Dallmeyer secondary magnifier of $7\frac{1}{2}$ inches focus placed 5 inches within the focus, and giving an image of the sun $1\frac{1}{2}$ inches in diameter; the camera furnished with six plate-holders, each taking two plates of 160 × 160 mm. (as in use for the Astrographic Chart), both plates being exposed by a quarter-turn of one shutter.

2. *The Cœlostat.*—The camera was pointed to a 16-inch cœlostat, the mirror of which was made by Dr. Common, the mounting and clock by Mr. J. Hammersley from designs by Dr. Common.

3. *The Polariscope.*—On the tube, and pointing to the same cœlostat, was a polariscopic apparatus consisting of an ordinary slit spectroscope (and telescope), with an Iceland spar double image rhomb substituted for the ordinary prisms. The instrument in its normal state had been used by Mr. Maunder in the 1886 eclipse expedition for photographing the spectrum of the corona. It is fitted with two plate-holders. The dimensions are as follow:—

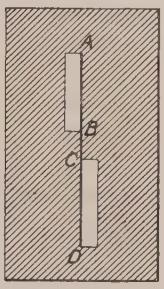
Objective.....	$3\frac{1}{2}$	inches aperture,	18	inches focal length.	
Collimator.....	$1\frac{1}{2}$	„ „	$6\frac{1}{2}$	„	„
Camera.....	2	„ „	9	„	„

The use of the apparatus will be understood from the analogy of the ordinary spectroscope, regarding the Iceland spar rhomb as a prism giving only two colours—the two kinds of polarised light. We can thus use a wide slit, opening it until the two images of the slit are just in contact without overlap. This was found to happen with the apparatus in use with a slit of width 0·19 inch. The

* One-half of a doublet photographic lens by Dallmeyer, belonging to Captain Abney, used in the Eclipse Expeditions of 1886, 1887, 1889, 1893, and 1896, acquired from him by the Royal Astronomical Society in 1893 for permanent use in eclipse expeditions, in consideration of their replacement by two others.

diameter of the sun's image thrown on the slit being 0·21 inch, it was thought best to take the two photographs, so as to include opposite limbs of the eclipsed sun, and as much of the corona as could be got. The change from one portion of the sun to another was arranged by having two slits as follows:—

The two slits were cut in a piece of blackened card, the actual size of which is shown in the diagram. If the line ABCD had been diametral to the sun's or moon's image, half the moon and corona would in the first instance have appeared in the middle of the lower slit, CD. In this position the first exposure was given, producing on the plate two images side by side of the right limb of the eclipsed sun, one image being due to light polarised in a plane



parallel to CD, and the other to light polarised in the perpendicular plane. For the next exposure the card was slipped down in the groove in which it fitted lightly, and the left limb of the eclipsed sun fell on the middle of the slit AB; and so two images of the rest of the corona would be obtained. By combining the two photographs, we could get a double picture of a slice of the corona 1·0 inch long and 0·40 inch wide, containing the moon centrally; or, translating inches into diameters of the moon's image, five diameters long and two diameters wide. As a matter of fact, the image of the sun was not adjusted centrally on the line ABCD, and a good deal more of the moon's disc appeared on one photograph than on the other, this being deliberately arranged for a special reason, which will appear in discussing the photographs obtained.

Instrumental Adjustments.

5. *Adjustment of Cœlostat.*—The adjustment of the polar axis was made as described in the Report on the Japan Expedition* by means of the attached declination theodolites.

The following are the actual observations, those with the level

* 'Monthly Notices,' vol. 57, p. 102.

being made on the meridian, and compared with the known latitude so as to give the same sign to the errors as the sun observations :—

Date.	Sun's H.A.	Obs. decl.	Tab. decl.	O.—C.
Jan. 11....	−4·0	−21° 45′	−21° 50′	+5′
		Observation with level		+3
	(Adjusted in azimuth and altitude.)			
	−3·0	−21 50	−21 49	−1
		Observation with level		0
	−1·0	−21 49	−21 48	−1
Jan. 17....	−3·7	−20 47	−20 45	−2
		Observation with level		0

[These observations were made with a dummy axis, before the mirror and its cell were mounted on January 19.]

Jan. 21....	−3·0	Observation with level		+6

[Adjusted level: probably disturbed by the weight of the mirror and its cell.]

	−2·0	Observation with level	0
	−2·0	−19 54 −19 54	0

[As there seemed some vibration in the instrument, the end of the arc holding the mirror was supported by a wooden block driven tightly under it; this again altered the level, which was readjusted.]

	0·0	−19 51	−19 53	+2
	0·0	Observation with level		+2
	+2·0	−19 49	−19 52	+3
Jan. 22....	−4·5	−19 37	−19 42	+5
		Observation with level		+2
„ 23....	−1·0	−19 24	−19 26	+2
		Observation with level		+3

It will be seen that the introduction of the wooden block as a partial support to the cœlostat disturbed the adjustments slightly, but it did not seem advisable to attempt to correct these small errors, which would have been a troublesome process with the stress of the wooden block to consider. The block certainly deadened the vibrations.

6. *Tilt of Mirror.*—If the mirror is not parallel to the axis of rotation the image will not be quite stationary.* Both instruments were tested for this error by reversing the mirror and cell in the Y's and noting the consequent displacement of the sun's image on the ground glass in the focal plane of the telescopes. The displacement,

* 'Monthly Notices,' vol. 56, p. 417.

giving double the inclination of mirror to axis, was found by C. on January 19 to be 7·2′; and was corrected after several trials to be 0·8′, denoting an error of 0·4′. The correction was made by screwing a short screw, made for the purpose, into one of the holes at the back of the mirror cell. [There are three of these holes, into which long screws are screwed in the operation of inserting the mirror into its cell.] T.'s mirror was examined on the same day, and being found to be sensibly parallel to the axis, no correction was necessary.

7. *Focussing of Telescopes.*—The method adopted was that described in the Report on the Japan Expedition.* The telescope was pointed normally to the mirror, and the image of a bright point or object in the plane of the film was photographed on the film.

A glass plate being cut in two, one half was blackened with asphalte, and the word "astronomy" printed on it by scratching with a needle point. This was the object photographed in the following experiments. Gauges had been made in England by means of which the three lenses (the Abney lens, the photoheliograph lens, and the Dallmeyer enlarging lens) could be set very accurately to positions in the wooden tube giving good focus. Positions at definite distances from these could be obtained by unscrewing the object glasses through fractions of a turn. If positions were required *within* the gauge position, the object glass was first *pushed* in slightly; and then it was noted what fraction of a turn it must be unscrewed to bring it to the gauge-position. Designating the gauge-position by zero, and one turn out by +1·0, one turn inside by −1·0, the following positions were tried:—

Abney Lens.

Plate 1, January 16, 0·0, +0·5, +1·0 positions. Three images on same plate, 0·0 the best.

Plates 2—5 were devoted to experiments on illuminants. A candle was found most convenient after all.

Plate 6, January 16, 0·0, −1·0, −1·5 (+0·5) positions; (+0·5) not on plate? 0·0 the best, if exposures rightly identified.

Plate 7, January 16, −1·5, −0·5, +0·5 positions; −0·5 the best of these.

Plate 8 (January 16). To make sure pushed still further in.

The above differences were slight, −3·0, −2·0, −1·0 positions, −1·0 the best.

Hence on this day focus seems at −0·5, or very close to it.

* 'Monthly Notices,' vol. 57, p. 105.

Dallmeyer Lens and Enlarger.

Plate 9, January 16, −1·0, 0·0, +1·0, +2·0 positions; 0·0 the best.

Plate 10, January 16, −0·5, +0·5, +1·5 positions; +0·5 the best.

Plate 11, January 17, 0·0, +0·25, +0·5, +0·75, 0·0 positions. Both 0·0 exposures were worse than the others.

Of the others 0·25 was perhaps best near the centre, and 0 5 (or 0·75 ?) further from centre.

Hence 0·5 was adopted, *i.e.*, the object glass was screwed one-half turn out. The screw has 12 turns to the inch; and the focussing was thus correct to 0·02 inch, as far as could be judged.

Abney Lens—(continued).

Plate 12, January 17, −1·0, −0·5, 0·0, +0·5, +1·0 positions; −1·0 best; −0·5 very good; 0·0, +0·5, +1·0 distinctly inferior.

This contradicts nothing but plate 6, on which the exposures may be wrongly identified, and if on that plate 0·0 is missing instead of +0·5, then −1·0 would be the best on the plate. *Hence −1·0 was adopted.*

[At 25 turns to the inch this focus was also correct to 0·02 inch.]

8. *Programme of Observations.*—The six slides for photographs of the corona were filled as below, the same plates being used for the Dallmeyer and Abney lenses in each case, and standard squares having been impressed on plates 2, 4, 5, 6, by Captain Hills, R.E, before sending the plates out from England.

No. of slide.	Exposure.	Plate.
1	1 sec.	Dry collodion "Gazelle."
2	5 secs.	Ilford "Empress."
3	10 „	Rocket.
4	20 „	Ilford "Rapid."
5	1 sec.	Ilford "Empress."
6	2 secs.	Ilford "Empress."

Besides these the two exposures through the polariscopic apparatus were made, each of 5 seconds' duration, Paget plates being used.

The developer used was amidol for all these plates, which were all successfully exposed.

9. *Times of Contacts.*—These were independently observed by Professor Turner and by Major Burrard, R.E. The former used for first and fourth contacts a pocket watch which was compared with the sidereal clock at 8.5 A.M. and found 29 seconds fast; and again at 8 P.M., and found 26·9 seconds fast, of local mean time. At second and third contacts he gave a sharp signal, the time of which was

noted by Mr. McA'Fee on a mean time chronometer, carefully compared with the clock both before and after. The contacts were observed by throwing a 4-inch image of the sun on white paper from a navy-pattern telescope. [Aperture 2 inches, focal length 28 inches, magnifying power of negative eyepiece 25.]

Major Burrard observed with a 2-inch telescope, and recorded his times on the chronograph in connection with the sidereal clock.

This clock was in a grass hut and subjected to a daily variation of 50° of temperature, but great care was taken with the star observations, as will be explained in detail in the final report of the Astronomer Royal. The local mean times of the star observations for clock error (by Major Burrard) were

January 21 days 18 hrs. 30 mins. 58 secs., and January 22 days 7 hrs. 21 mins. 13 secs, and the errors of the clock at these times were, +0 min. 12·83 secs. and +0 min. 14·88 secs. respectively.

Local Mean Times of the Four Contacts.

Observer H.T.	Observer B.	Calculated time.	Calculated from 'N.A. Circular, No. 16,' with formulæ for	
			Nagpur.	Benares.
hrs. mins. secs.	secs.	secs.	secs.	secs.
I. 0 13 11·7	22·8	6·3	11·3	8·8
II. 1 41 3·0	3·3	5·4	12·3	9·3
III. 1 42 48·5	47·9	52·0	67·3	49·3
IV. 3 1 40·2	35·7	51·3	63·7	45·3

10. *Remarks on Formulæ for Prediction of Contacts.*—As was mentioned in paragraph 5 of the joint report of the Astronomer Royal and Professor Turner, the data for predicting the four contacts were found insufficient. This will be seen by comparison of the last two columns, wherein the times as given by the published formulæ most nearly suitable for Sahdol are given. On application to the Superintendent of the 'Nautical Almanac,' he kindly supplied the data for the third column, giving the G.M.T.s of the four contacts, to which the longitude of Sahdol has been applied.

[The position of Sahdol is

5 hrs. 25 mins. 26·2 secs. E., Lat. 23° 16′ 45″ N.]

As his letter contains a suggestion which may be useful to other observers, I reproduce it here.

"Nautical Almanac Office,
"March 26, 1898.

"Dear Turner,

"You will find the deduction of the formulæ (used in 'N.A. Circular No. 16' and others) in appendix to N.A. 1836, p. 117. These equations will give sensible accuracy for a distance of about 50 miles from the point for which they are computed. In this case the distance is about 150 miles.

"I find that the most expeditious way of getting accurate results in this work, is to use the Besselian Elements (page 4 of circular No. 16). You can infer the time of middle of eclipse to the nearest minute from the Table on p. 3 of circular, and then 10 minutes work gives you the times of beginning and ending of totality with sensible accuracy.

"Of course for accurate determinations of times of first and last contacts (partial phase) special computations for the approximate times of these contacts would be necessary.

"Yours very truly,
"A. M. W. Downing."

The following remarks on the geometrical significance of these formulæ may not be out of place.

The time of a contact t at a place of geocentric latitude l and longitude λ is given by a pair of equations of this form

$$\cos\omega = A + B\sin l + C\cos l\cos(\lambda + D)$$

$$t = E + F\sin\omega + G\sin l + H\cos l\cos(\lambda + K).$$

Write these in the form

$$\cos\omega = A + L\{\sin l\sin l_0 + \cos l\cos l_0\cos(\lambda - \lambda_0)\} = A + L\cos PP_0,$$

$$t = E + F\sin\omega + M\{\sin l\sin l_1 + \cos l\cos l_1\cos(\lambda - \lambda_1)\}$$
$$= E + F\sin\omega + M\cos PP_1,$$

where P is the point (l, λ) and P_0 a point whose geocentric latitude and longitude are l_0 λ_0 given by the equations

$$C\tan l_0 = B = L\sin l_0, \qquad \lambda_0 + D = 0,$$

and PP_0 is the arc of the sphere between P and P_0.

Similarly for the point P_1.

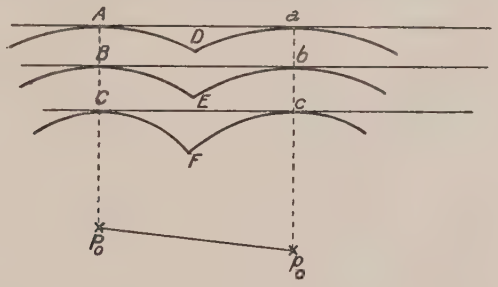
In the case of the second and third contacts, which determine totality, the equations only differ in the sign of F: so that the duration of totality is constant when ω is constant. The condition $\omega = 0$ gives us points for which the eclipse is just total for an instant, *i.e.*, the points on the borders of the totality belt. But from the equation

$$\cos\omega = A + L\cos PP_0$$

we see that ω is constant when the arc PP_0 is constant, *i.e.*, along the arc of a small circle described with centre P and radius PP_0.

The bounding lines of the totality belt given us by the approximate formulæ of the 'Nautical Almanac Circular,' are thus portions of small circles of the sphere.

Now, suppose we have formulæ given for the neighbourhoods of two points B and b on the central line; for which P_0 and p_0 are the centres of the approximate loci of equal totality. Then the approximate formulæ for B will give us as the northern boundary of the



totality zone the circular arc AD, touching the true line at A, but falling south of it elsewhere; and the approximate formulæ for b will give us the arc aD. Thus at the intermediate point D, both formulæ give errors in the same direction; and unless the points B and b are tolerably close together we cannot get a good prediction for intermediate points by simple interpolation.

The true lines Aa, Bb, Cc, are the *envelopes* of such circles as AD, BE, CF, as we travel along the central line, P_0 travelling along the path P_0p_0 in correspondence.

It is to be noted further, that the approximate formulæ give a constant duration of totality along the line BE, which is the approximate central line (given by $\sin \omega = 1$): whereas the duration generally changes as we go east or west. But interpolation between results for B and b would probably give the means of allowing for this change.

If instead of the duration of totality, we take the time of one of the contacts, the approximate loci are no longer circles, but curves of the form

$$(a + b \cos PP_0)^2 + (c + d \cos PP_1)^2 = 1,$$

and the geometry is less simple; but these curves will have the true line for their envelope just as the circles did.

Now, if the contact of the circles or the curves with their envelope is of the *second order* interpolation becomes possible, for the circles cross the envelope and thus the error introduced is + to the east

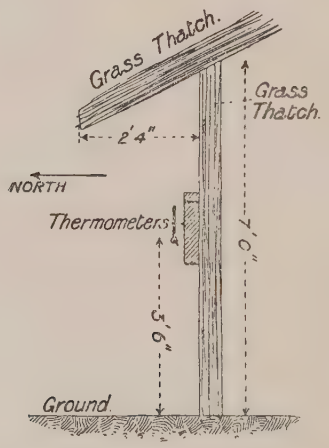
and — to the west. The test of this is to calculate the contacts for b with the constants given for B, and compare with true values for b; similarly calculate the contacts for B with the constants given for b and compare with the true values for B. If the errors are of opposite signs, then the curve crosses the envelope, and the contact is of the second order. A few experimental calculations of this kind, with the data of 'N.A. Circular, No. 16' seem to show, however, that the contact is not generally of the second order, and the approximations are thus subject to the disadvantages above indicated.

11. *Meteorological Observations.*—Lieut. Crosthwait, R.E., has kindly supplied the following particulars of the meteorological observations:—

They were made from 1898, January 14, to January 24 inclusive, by the following observers:—

Venayek Narayan, Narayan Vishnoo Apte, Govind Ramchandra Bhabhi, and Vishnoo Babaji Garnd.

The thermometers were attached to a board suspended to the north side of a grass hut, with an overhanging roof, completely shading them from the sun's rays at all times of the day. Height above ground and other dimensions shown in accompanying diagram.



The situation is open, facing towards the north, on a gently undulating plain, about 1500 feet above sea level. The only hills in the neighbourhood are from 2000—3000 feet high, distant about 12 miles.

The following instruments were used: A maximum and minimum thermometer No. 20,443 by Hicks; a wet and dry bulb No. 38,037 by Negretti and Zambra; a mountain mercurial barometer, standing on a tripod, No. 1824 by L. Casella.

Before beginning, the following comparisons were made with a standard thermometer No. 93,638 by Casella :—

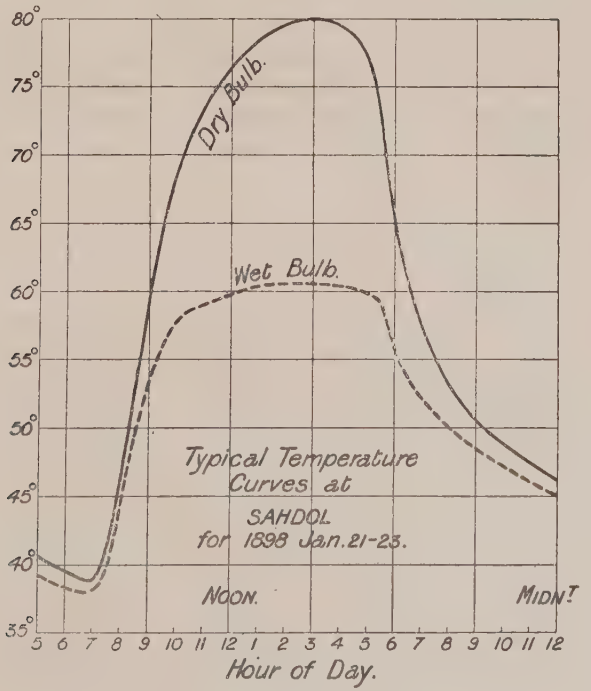
Standard read	78·6°		
Dry bulb ,, ...	77·9	correction	+0·7°
Wet ,, ,, ...	78·0	,,	+0·6
Maximum ,, ...	78·0	,,	+2·6
Minimum ,, ...	78·0	,,	+0·6

The wet and dry bulb thermometers, and the barometer with its attached thermometer, were read every half hour from 5 A.M. till 8 P.M. or later. The maximum thermometer was read at 4 P.M., the minimum at 10 A.M.

On the day of the eclipse, observations were made of wet and dry bulb and barometer, and also of the standard thermometer (Casella No. 93,638) every five minutes.

The barometer was very steady throughout our stay, near 28·6 in. ; and it seems scarcely necessary to publish the details.

The wet and dry bulbs both followed very closely the curves shown in the attached diagram, the deviations from the curve seldom exceeding a degree or two. To avoid needless printing, the follow-



ing particulars for a number of readings on January 21, 22 and 23 are given as illustrations:—

Excess of Readings of Thermometers over the Typical Curves shown in the Diagram.

Hour.	Dry bulb. Jan. 21.	Dry bulb. Jan. 22.	Dry bulb. Jan. 23.	Wet bulb. Jan. 21.	Wet bulb. Jan. 22.	Wet bulb. Jan. 23.
6 A.M.	−1·9°	−1·3°	+1·1°	−1·6°	−0·6°	+0·8°
8 „	−1·4	+0·5	+2·0	−1·8	−0·3	+1·8
10 „	−1·5	+1·5	+2·8	−0·8	−0·6	+1·1
Noon	−2·6	+1·3	+1·9	−0·8	+0·2	+0·8
1 P.M.	−1·6	0·0	+2·0	−1·9	−1·0	+2·1
2 „	−0·8	−9·0	+1·0	−1·6	−3·5	+1·5
4 „	−0·6	−2·6	+0·4	−0·3	−0·5	+1·5
6 „	+3·0	−2·3	+1·1	+0·2	−0·6	−0·9
8 „	−1·6	−0·6	+2·0	−1·6	+0·1	+1·8
10 „	−1·9	+0·3	+2·3	−0·8	+0·6	+1·8

[The anomalous readings of dry bulb at 6 P.M. on January 21, and of wet bulb at 6 P.M. on January 23, are apparently not mistakes, unless the neighbouring observations are similarly affected.]

We may thus take it that the typical curves of the diagram represent with considerable accuracy what would have been the state of things on January 22, if the eclipse had not taken place.

Comparing then the readings during the eclipse with this curve, we get the following differences, which may be regarded as the effect of the eclipse.

Effect of the Eclipse on Temperature as shown by Five-Minute Readings.

Time of day. hrs.	mins.		Dry bulb.	Wet bulb.
0	0	(Noon)	+1·2°	−0·1°
0	5		0·0	−0·7
0	10		+0·8	−0·2
0	15	First contact	+1·7	+0·2
0	20		+1·5	+0·1
0	25		+0·8	−0·9
0	30		+0·6	−0·5
0	35		+0·4	0·0
0	40		+0·3	−0·1
0	45		+0·2	−0·1
0	50		−0·5	−0·2
0	55		−0·6	−0·4

Effect of the Eclipse on Temperature as shown by Five-Minute Readings—*continued.*

Time of day. hrs.	mins.		Dry bulb.	Wet bulb.
1	0		−1·3	−0·8
1	5		−1·9	−0·8
1	10		−2·0	−1·3
1	15		−2·2	−1·4
1	20		−2·8	−1·9
1	25		−3·4	−1·9
1	30		−4·0	−2·5
1	35		−4·0	−2·5
1	40	Totality	−5·1	−3·5
1	45		−7·2	−3·5
1	50		−7·7	−3·5
1	55		−8·3	−3·6
2	0		−8·9	−3·6
2	5		−8·5	−3·1
2	10		−7·6	−2·6
2	15		−6·7	−2·2
2	20		−5·7	−1·9
2	25		−5·1	−1·7
2	30		−4·4	−1·7
2	35		−3·4	−1·5
2	40		−3·7	−1·4
2	45		−3·5	−1·2
2	50		−3·5	−1·2
2	55		−3·1	−0·6
3	0	Last contact	−3·1	−0·6
3	30		−2·6	−0·3
4	0		−2·5	−0·2

"Total Solar Eclipse of January 22, 1898. Preliminary Report on Observations made at Ghoglee, Central Provinces." By Professor RALPH COPELAND, Astronomer Royal for Scotland. Received May 10, 1898.

In the month of August, 1897, I was invited by the Joint Permanent Eclipse Committee to take part in observing the total solar eclipse which occurred in India on 22nd January of the present year.

The preparation of the equipment, which will be described further on, was at once proceeded with, and by the sanction of the University authorities and the Secretary for Scotland I was granted the

necessary leave of absence from the University and the Royal Observatory.

Having shared in the general disappointment of the Russian eclipse of 1887, and the no less unfortunate visit to Vadsö in 1896, I resolved on this occasion to occupy a separate station at some distance from any large group of observers. My only companion was our observatory engineer (James McPherson), who on the two previous occasions had shown his skill and energy in setting up and handling the instruments.

A grant of £180 was made to me by the Committee. This would have been amply sufficient had I dispensed with the services of Engineer McPherson, but without his aid I could not have carried out my plan of occupying an independent station and using several instruments.

Our equipment consisted of—

(1) A horizontal telescope of 38 feet focus and 4 inches aperture to be used with a fixed mirror, the image being received on 18-inch plates moved by clockwork. This instrument was provided with a direct vision prism mounted on a slide in front of the object-glass, which, when drawn into position by an attendant, transformed the telescope into a prismatic camera.

(2) A small prismatic camera designed for the investigation of the ultra-violet rays of the solar appendages. To this end the object-glass was of quartz and Iceland spar, the prism being of the latter material.

(3) A slit spectroscope by Grubb, with one compound prism. (2) and (3) were carried by a 4-inch equatorial mounting, and served to balance each other.

(4) A 4-inch camera with a doublet lens, by Dallmeyer, of 33-inch focus, mounted on a 3-inch equatorial stand. Both the equatorial mountings were fitted with driving clocks.

In place of a hut we were provided with a supply of laths, boards, and brown paper, plain as well as waterproof and blackened, for building the camera of the 40-foot, which had also to serve as a dark room. The hut built with these materials served the intended purpose satisfactorily. It was ventilated by a tin chimney like that of a magic lantern.

The instruments were despatched on the 20th November, *viâ* Leith and London, to Bombay. Engineer McPherson left Edinburgh on the 2nd December to embark in London on board the P. and O. s.s. "Britannia," while I, leaving on the 8th, was able to catch the same steamer at Brindisi on the 12th December. Bombay was reached on the 26th December, and Nagpur, in the Central Provinces, two days later. Here we were most hospitably received by Colonel Henry J. Lugard (Madras Staff Corps), and with his help

and that of his son, Mr. Edward Lugard, Executive Engineer, Bhundara, a station was finally selected on the last day of the year, close to the village of Ghoglee, 16 miles north-west of Nagpur, and about 2 statute miles south-east of the line of central eclipse. On New Year's Day I observed the sun for latitude, time and azimuth, and on the 2nd January we began our camp life, having lived meanwhile at Kalmeshwar, in a bungalow belonging to the Department of Works, three miles distant, on the way to Nagpur. We found the large double tent provided by the Government most comfortable. It was pitched beside a grove of mango trees, under which was a large well with a plentiful supply of water. On the 4th January concrete foundations were begun for the fixed mirror and lens, for the plate-carrier of the long-focus telescope, and for each of the two equatorials. The latter were placed in line with the dark room of the horizontal tube, so as to bring the observers within earshot of the metronome which was used to regulate the lengths of the exposures. It is needless to give particulars respecting the adjustments of the equatorials, which were considered sufficiently accurate when within two minutes of arc of the truth.

The method pursued with the horizontal telescope was as follows :— With the theodolite placed on the proposed centre line of the tube, the azimuth of a distant tree was found from observations of the sun, and also of the pole star. Two sets of footholes for the theodolite were made in blocks of cement at different levels, but referred to a common centre. By this means the theodolite could be used either as a collimator looking through the lens of the long telescope, or as a directing telescope to bring the tube, lens, and plateholder exactly into the required line. The fixed mirror was roughly adjusted as regards azimuth with the theodolite and a reflecting eye-piece, and as to inclination by means of a gauge and spirit level. The final adjustment was given by slightly turning the slow motion screws of the mirror until the sun's image ran along a parallel of declination drawn on the cover of the plate-holder, and also crossed one or other of a set of vertical lines at a given computed time. The tube being set exactly horizontal, the plate-holder was "squared on" by viewing the image of the object glass in a mirror held against the plate-holder in reversed positions. The long-focus object glass was "squared on" with the help of one of the little centering telescopes originally designed by Fraunhofer. The inclination of the slide on which the plate-holder ran was found from the computed altitude and azimuth of the sun's centre two minutes before and two minutes after mid-totality. The same data also gave the speed at which the plate had to move—in our case 1·872 inch per minute. No provision was made to counteract the very slight effect of the rotation of the sun's image during the period of exposure. The

sliding frame was drawn forward by a wire cord and weight, the rate of motion being regulated by the speed at which the driving clock "payed out" the cord. A tendency to advance by jerks was altogether removed by thoroughly strengthening the clock seat-board and its attachment to the fixed frame. The clock, kindly lent by Lord McLaren, was made by Sir Howard Grubb. We utilised the slide motion to obtain a chronographic record of the exposures. Three pencils, in holders hinged to the standing part and moved by strings, marked the time on a slip of paper pasted on the back of the moveable frame.

The distance of the plate-holder from the cell of the lens had been found in Edinburgh to be 455·27 inches. This interval was set off in India with light wooden rods, which were compared with a Chesterman steel foot-rule. The photographic focus of the Dallmeyer 4-inch had been found to agree exactly with the visual focus. The instrument was focussed in India with the help of a focussing glass, both in the day-time on an object at a distance of 440 yards, and on stars at night, in the former case making allowance for the divergence of the rays by means of the well-known formula for conjugate foci. The two results were practically identical, but differed considerably from the scale reading used at home, owing to the shrinking of the wooden tube, in which the grain runs crosswise. The tube of the Iceland spar camera, being made of well-seasoned teak, was found unchanged in length, as proved by the linear spectra of Sirius and γ Argûs.

The greatest difficulty was experienced in filling the plate-holders of the long-focus telescope. It was only after many hours spent in paring and rasping the twisted frames that the plates were adjusted and ready for exposure. Two plates were broken in the process.

Our programme was as follows:—Eight plates, 18 inches square, to be exposed by Engineer McPherson standing in the dark room, where he had control of the cord for opening the spring shutter, were provided for the horizontal telescope, each carried in a separate holder. The prism was to be pulled into position by our native butler, Vardhya, at a signal from McPherson.

Mr. Meehan, Assistant Engineer of the Public Works Department, had kindly volunteered to work the Dallmeyer camera. He was provided with nine quarter plates, mounted in three long slides. The shutter was of the ordinary pneumatic kind.

I took charge of the ultra-violet prismatic camera, with six plates in three reversible holders. I had also one plate (Cadett) in the Grubb spectroscope, which was to be exposed by simply drawing back the slide. Cadett plates were used for the horizontal telescope and the 4-inch, while partly Lumière and partly Cadett plates were to be tried in the prismatic camera.

Mr. Meehan came in good time on the morning of the 22nd in order to have a final opportunity of practising the management of the 4-inch. Everything being prepared to the best of our ability, I anxiously watched with the finder of the prismatic camera for the first contact. The first indentation in the sun's limb was not perceived until 11 secs. after the computed time, but as the telescope only magnified thirteen times, and there was a chance that the prediction might be slightly wrong, this agreement was considered satisfactory. Ten minutes before the beginning of totality the observers took their assigned stations, and a little later the metronome was set going 2 mins. 14·6 secs. before the computed total phase, McPherson saw the following edge of the diminishing sun's image exactly on the line which had been previously marked on the sliding frame. 20 secs. later he started the clock in accordance with a signal given by me, and after about a quarter of a minute had elapsed each observer made a mark on the chronograph slip in response to the measured "one, two, three," called out by me in time with the beats of the chronometer. From this moment, which was 40·8 secs. before the computed disappearance of the sun, I watched the shortening line of light with the finder. It seemed a long time in disappearing, but the sunshade was so dark that I felt sure that nothing but the photosphere could be seen through it. I therefore refrained from giving any signal until the last trace of light had disappeared. I then called out "totality," as previously arranged, and had the satisfaction of hearing the shutter of the 38-foot (which made a rather loud noise) closing at the end of McPherson's first exposure.

The whole of the eight plates were successfully exposed in the horizontal telescope.

	Exposure.	Object.
No. 1	1·4 secs.	Corona.
2	6·7 „	Corona.
3	3·8 „	Spectrum.
4	6·7 „	Spectrum.
5	9·5 „	Corona.
6	13·2 „	Corona.
7	5·4 „	Corona.
8	1·0 sec.	Spectrum.

The five photographs of the corona are much disfigured by an exhalation thrown off by the bass wood of which the plate-holders are made, which has caused the grain of the wood to print itself in broad streaks on the pictures. By combining the various negatives in one drawing, however, there is reason to believe that the details of the brighter parts of the corona can be satisfactorily worked out. Plates 3 and 4 show very distinct spectral images

of the prominences corresponding to a number of lines in the violet region of the spectrum. On the last plate, which was exposed very shortly after the end of totality, there is a broad spectral band full of bright and dark lines of varying intensities, corresponding to irregularities in the sun's limb and the presence or absence of prominences. Many of the bright lines run out into the cusps. The scale of this photograph is such that H and K are 10 mm. apart. By an oversight the prism was not used with Plates 1 and 2 as was originally intended.

Mr. Meehan also exposed the whole of the nine plates allotted to him. Three of these show the coronal rays during totality. The fourth has the coronal streamers quite distinct, although the sun is already reappearing with a trace of Baily's heads. The fifth plate, taken several seconds later, shows the solar crescent still further disclosed, but with the whole of the moon's disc distinctly outlined against the background of corona. In the last plate there is nothing to be made out beyond the over-exposed solar crescent; the remaining three plates are blank. I am under great obligation to Mr. Meehan for his valuable assistance with this instrument, as well as for help in other directions.

In the small prismatic camera four plates proved to be as many as I could dispose of. The actual exposures attempted were 2·5 secs., 4·7 secs., 19·6 secs., and 14·0 secs. respectively. The resulting negatives show numerous rings and lines ranging from 1474 K to about W.L. 3000. The lines are sharpest in the first plate, while the 1474 K ring comes out more fully in the second and fourth negatives. The third plate is unfortunately blank.

The plate in the integrating spectroscope, which was used without a condensing lens, shows a spectrum of three strong bright lines with a number of feebler ones between them. With an exposure of about a minute, terminating just before the end of totality, the plate is decidedly under-exposed.

The makeshift chronograph, while working well for the other two observers, failed to record Mr. Meehan's signals distinctly, owing probably to the greater length of the cord required to reach his telescope.

On Wednesday, 26th January, we broke up our camp at Ghoglee and sailed from Bombay on the 29th, reaching Edinburgh on the 21st February.

I wish here to record my indebtedness to all the officials and private individuals, British and native, by whose kind aid the object of the expedition was so much furthered and our visit to Central India made so pleasant as well as scientifically interesting.

"Total Eclipse of the Sun, January 22, 1898. Preliminary Account of the Observations made by the Eclipse Expedition and the Officers and Men of H.M.S. 'Melpomene,' at Viziadrug." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received March 28, 1898.

LOCAL ARRANGEMENTS.

After various inquiries which I had made respecting the suitability of Viziadrug for observations of the total eclipse, I informed the Eclipse Committee that I was prepared to take charge of an expedition to that locality, and it was agreed that the observations at this station should be placed in my charge.

The latitude and longitude of the part of the fort at Viziadrug finally occupied were 16° 33′ 26″ N. and 73° 18′ 58″ E. respectively, and the duration of totality was estimated at 127 seconds.

In connection with the work at this station the Admiralty was asked for a ship of war to convey the observers from Colombo to Viziadrug, and to permit the use of the ship, if possible, as a base, to enable me to repeat the observations attempted in Norway in 1896 with the assistance of H.M.S. "Volage," which ship supplied twenty-four assistants during the eclipse and fifty volunteers for general observations.* As a result of the Royal Society's application, H.M.S. "Melpomene," in command of Captain Chisholm Batten, R.N., was told off to join the expedition.

The expedition, which left England on December 10, consisted of Mr. A. Fowler, Dr. W. J. S. Lockyer, and myself, together with the Marquis of Graham, who joined as a volunteer. Some little time after reaching Viziadrug Professor Pedler, F.R.S., joined the party from Calcutta, and shortly before the eclipse Mr. John Eliot, Meteorological Reporter to the Government of India, joined from Simla. On arrival at Colombo we found H.M.S. "Melpomene" waiting there, and at once proceeded to the selected spot of observation—Viziadrug.

During the three days' voyage to our station a call for volunteers was made by Captain Batten, and 120 came forward. Lectures and demonstrations were therefore at once commenced by Lieutenants Blackett, Colbeck, and Dugmore, second engineer Mountfield, and myself to the several parties of men who had undertaken to perform special pieces of work. Twenty-two separate groups of observers were formed. On our arrival at Viziadrug we were received very kindly by Mr. Bomanji, the collector of Ratnagiri, and an Overseer of the Public Works Department, who was on the spot in charge of

* 'Phil. Trans.,' A, vol. 190 (1897), pp. 1—21.

some most excellent masons and carpenters, picked men from Ratnagiri as we later ascertained, and plenty of material for the construction of the necessary concrete bases and huts. It was important to erect the huts as soon as possible, not only to shelter the instruments but the observers from the sun. Several screens were made which could be moved and placed in any required position; these were found to be invaluable while the instruments were being erected. A considerable number of coolies was also present to do such work as carrying packing-cases, sawing wood, clearing the camp, &c.

In the fort was also a police guard sent from Ratnagiri. The camp was watched both by day and night so effectively by them that no damage to any instrument was reported.

On the arrival of the "Melpomene" at Viziadrug, Mr. Bomanji came on board to report the arrangements which had been made for the expedition by the Government of India. As these were not quite completed, it was necessary for the first few days to return to the ship every evening, but afterwards Mr. Fowler, Dr. Lockyer, and myself took up our quarters at the Dak bungalow inside the Fort, close to the instruments. Meals were provided at the Collector's camp, which was also inside the Fort.

A party was landed at the fort on the afternoon of our arrival to inspect the site suggested by Mr. Bomanji, and it was at once evident that it would satisfy all requirements, provided the fluctuations of temperature of the great masses of masonry composing the fort had no disturbing influence on the steadiness of the air. In order to investigate this point a $3\frac{3}{4}$-inch telescope was erected, and observations of the surrounding landscape, and, at dusk, of various stars, were made, from which it appeared that the atmosphere was sufficiently steady for the observations.

Next morning the instruments were landed and the concrete bases for them were commenced. The erection of the huts was also begun by the native workmen and continued without intermission.

The instruments were set up as soon as their bases were ready, and by the end of a week all were practically in readiness for the eclipse. Constant clear skies enabled all the adjustments to be made without difficulty.

During the week preceding the eclipse the adjustments were frequently tested, and a complete system of drills was established.

As the number of volunteers was so large I pointed out to Captain Batten, who had volunteered to aid in a special branch of the work, the importance of his taking charge of the whole camp and giving all the necessary orders for conducting the operations during the general rehearsals, and the eclipse itself. He eventually agreed to this, and the procedure and time signals were arranged between us.

The groups of observers were as follows:—

1. Time.
2. 6-inch prismatic camera.
3. 9-inch „ „
4. Integrating spectroscope.
5. 6-inch equatorial.
6. Coronagraph.
7. Discs.
8. Sketches of corona without discs.
9. $3\frac{3}{4}$-inch equatorial.
10. Observations on stars.
11. Shadow-bands.
12. Meteorological observations.
13. Hand spectroscopes.
14. Prisms for rings.
15. Polariscope.
16. Landscape colours.
17. „ cameras.
18. Shadow phenomena.
19. Kinematograph for eclipse.
20. „ „ shadow.
21. Contact observations.
22. Observations on natives, animals, &c.

The observers were as follows:—

1. *Time Signals.*

Captain A. W. Chisholm-Batten, R.N.
F. Downton, Leading Seaman.
W. Woods, Yeoman of Signals.
W. Groves, Shipwright.
F. T. Marey, Private, R.M.L.I.
G. S. Fullilove, Private, R.M.L.I.
G. Cleary, Private, R.M.L.I.

2. *6-inch Prismatic Camera.*

Mr. Fowler.
Lieutenant O. de Wett, R.N.
C. Ironsides, G.M.
J. Turner, T.I.
F. Brading, A.B.
J. Innes, A.B.
G. Salt, Boy, 1st Class.

3. *9-inch Prismatic Camera.*

Dr. Lockyer.
Lieutenant Percival-Jones, R.N.R.
A. Ramage, A.B.
W. Bray, Ch. Arm.
A. Wilkins, Shipwright.
E. Ashford, A.B.
F. Fenton, A.B.
A. Carr, Boy, 1st Class.

4. *Integrating Spectroscope.*

Lieutenant G. C. Quayle, R.N.
J. Bird, Ch. E.R.A.
G. Travill, P.O., 1st Class.

5. *6-inch Equatorial with Grating Spectroscope.*

Sir Norman Lockyer, K.C.B.
Professor A. Pedler, F.R.S.
Mr. R. C. Steele, Gunner, R.N.
P. Ross, Ch. E.R.A.
G. Vanstone, Ch. E.R.A.
H. Brown, Ship's Steward's boy.

6. *Coronagraph.*

Staff-Engineer A. Kerr, R.N.
W. Holmes, E.R.A.
C. Moseley, Leading Stoker, 1st Class.
G. Collier, Stoker.

7. *Discs.*

A. Ruse, Ship's Corporal, 1st Class.
G. Pink, Qualified Signalman.
J. Henry, Boy, 1st Class.
R. Sutherland, Leading Signalman.
W. Webb, A.B.
W. Corney, Stoker.

B. Brook, Stoker.
A. McDonald, P.O., 1st Class.
A. Tull, Ship's Steward's Boy.
G. Price, A.B.
J. Jones, A.B.
F. Dibbins, Ordinary Seaman.

L. Pettingale, Leading Signalman.
W. Brooker, A.B.
S. Drew, Ordinary Seaman.
L. Gates, A.B.
R. Davis, A.B.
P. McKenna, A.B.

8. *Sketches of Corona without Discs.*

A. Richardson, P.O., 1st Class.
W. Pankhurst, A.B.
H. Lack, Boy, 1st Class.
} General.

T. Wells, A.B.
H. Brinstead, A.B.
} N.W.

E. Dann.
W. Evans.
} S.E.

W. Anderson, A.B.
E. Wilson, Ordinary Seaman.
} N.E.

W. Clayton.
A. Penny.
} S.W.

9. *3¾-inch Equatorial.*

Sir Norman Lockyer, K.C.B.
Mr. H. Willmore, Assistant Engineer, R.N.
M. Moore, Stoker.

10. *Observations on Stars.*

Lieutenant Henry Blackett, R.N.
J. McDonald, A.B.
F. Stevens, A.B.
R. Buckland, Plumber's Mate.
T. Sutton, Stoker.
J. Fitzroy, Boy, 1st Class.
G. Russell, Private, R.M.L.I.

11. *Observations of Shadow-bands.*

Staff-Surgeon C. L. Nolan, R.N.
C. Hester, Private, R.M.L.I.
A. Purkington, 2nd S. B. Steward.

12. *Meteorological Observations.*

Mr. John Eliot, C.I.E., F.R.S.
J. Russell, Chief Stoker.
C. Butt, Leading Stoker, 1st Class.
H. Rockett, Stoker.
A. Wallace, Stoker.
G. Pratt, Stoker.
H. Wallburn, Stoker.
J. Bartlett, Stoker.
T. McCarthy, Stoker.
E. Perry, Stoker.
G. Woolston, Stoker.
G. Garrard, Stoker.
C. Mintram, Stoker.
P. Keefe, P.O., 1st Class.

13. *Hand Spectroscopes.*

Lieutenant C. E. B. Colbeck, R.N.
C. Kitchingham, Private, R.M.L.I.
C. Woodley, P.O., 1st Class.
P. Manning, Ordinary Seaman.
H. Mitchell, Stoker.
J. Dobson, Sergeant, R.M.L.I.

14. *Prisms for Observations of Ring Spectra.*

Mr. J. Mountifield, Senior Engineer, R.N.	R. Coates, Stoker.
W. Morris, E.R.A.	G. Tarrant, Stoker.
A. Howe, E.R.A.	H. Warren, Stoker.
C. Stacey, Leading Stoker, 2nd Class.	J. Inch, Stoker.
H. Knight, Leading Stoker, 2nd Class.	G. Gray, Chief Stoker.
	J. Cross, Stoker.

15. *Polariscope.*

Staff-Surgeon C. L. Nolan, R.N.

16. *Landscape Colours.*

Lieutenant E. N. R. Dugmore, R.N.	P. Darvil, Boy, 1st Class.
G. Farrell, Boy, 1st Class.	H. Rhodes, Ordinary Seaman.
W. Jacobs, A.B.	H. Attree, Signalman.

17. *Landscape Cameras.*

Mr. Turner, Survey Department, Calcutta.	J. Collins, Chief Stoker.
E. Gyngell, A.B.	J. Kearney, Leading Stoker, 1st Class.
H. Childs, Chief Stoker.	E. Cross, Leading Stoker, 2nd Class.

18. *Shadow Phenomena.*

W. Keenan, Chief Carpenter's Mate.	G. Riley, Stoker.
A. Reynolds, Stoker.	B. Crunden, Stoker.
W. Weeks, Shipwright.	C. Carpenter, Stoker.

19. *Kinematograph for Eclipse.*

The Marquis of Graham.	C. Thomas, Seedie.
A. Shilcock, E.R.A.	P. King, Ordinary Seaman.
E. Green, Boy, 1st Class.	W. Cronen, Stoker.

20. *Kinematograph for Shadow.*

Mr. H. P. Barnett, Paymaster, R.N.	A. Gidney, E.R.A.

21. *Contact Observations.*

Lieutenant O. de Wet, R.N.	C. Ironsides, G.M.

22. *Observations on Natives, Animals, &c.*

W. J. C. Slocombe, Ordinary Seaman.	F. Beal, Ordinary Seaman.
G. Whittingstall, Ordinary Seaman.	

Aides-de-Camp to Sir Norman Lockyer, K.C.B., F.R.S.

Mr. W. H. P. Bourne, Midshipman, R.N.	J. Hunt, P.O., 2nd Class.

The development of the photographic plates was commenced immediately after the eclipse, and it was found that the results were on the whole very satisfactory. No results, however, were obtained with the integrating spectroscope, and the kinematograph films taken by Lord Graham were too badly fogged to serve any useful purpose.

The dismantling of the instruments was commenced very soon after the eclipse, and the packing, together with the development and copying of the negatives, kept the party fully occupied until the morning of January 25, when the expedition left Viziadrug.

Half of the negatives and glass copies of the remainder were conveyed to England in charge of Mr. Fowler, while the remaining half of negatives and positives were sent home *viâ* Bombay.

The general time signals were given by a bugler under Captain Batten's orders. The chronometer was in charge of Lieutenant de Wet, R.N.

For the work of the prismatic cameras it was important to get a signal as nearly as possible five seconds before the beginning of totality, and, in order to eliminate the possible error of the chronometer, it was arranged to determine this by direct observations. Two methods were adopted. In one of them a boat was moored at a distance of two miles from the camp, in the direction of approach of the shadow, which would pass this point five seconds before totality. This failed because of the indefinite boundary of the shadow.

The other method was to determine when the visible remaining crescent subtended an angle of 45°; calculation showed that this would occur at the desired interval from totality. This method was completely successful.

The special signals during totality were given every ten seconds, beginning at 127—the assumed period of totality—by means of the eclipse clock (which was started at the signal "go" by cutting a thread thereby releasing the pendulum), by two timekeepers, one during the first half, the other during the second half of totality.

In the system adopted not only was the time left called out every tenth second, but other signals were interpolated to guide the work in the photographic huts. In order that there might be no mistake about the calls, a spiral was drawn on the clock-face and the seconds left plainly marked at the points which the second hand would occupy during its two revolutions.

In consequence of the perfect drill acquired at the rehearsals the operations went off during the eclipse with absolute steadiness. They commenced about one and a half hours before totality, ending after a like interval after totality. Six volunteers were employed in the timekeeping, including three with lamps which were not wanted.

The Chief Instruments employed.

The Prismatic Cameras.

In the two prismatic cameras no less than fifty-seven photographs were secured, the exposures varying from one to fifty seconds. Such a result as this could only be obtained by a minute subdivision of labour. In the case of each of these two instruments six volunteers were employed, and they were distributed in the following manner:—

One observer with the finder, his duty being to keep the image

in the centre of the field of view which corresponded (by previous adjustment) to the centre of the plate in the prismatic camera. He had a timekeeper to record the times of contact.

A third acted as timekeeper to record the exact moments at which the exposures were begun and ended.

A fourth volunteer, by means of a piece of cardboard, covered and uncovered the front of the prism, from directions given by Mr. Fowler and Dr. Lockyer respectively.

In one case two, and in another three, men were required to hand and receive the large dark slides before and after exposure, taking them out or placing them back in bags made for this purpose.

Six-inch Prismatic Camera.

This instrument, the dispersion of which had been increased this year by the addition of a second prism, was worked by Mr. Fowler, with the assistance of Lieut. de Wet and five men. Mr. Fowler's programme was to begin taking a series of ten snap-shot pictures five seconds before the commencement of totality, to obtain a record every second or thereabouts of the spectrum of the chromosphere. After this he exposed eight other plates to secure photographs of the coronal rings, the exposures being of various lengths. It was also arranged that at five seconds before the end of totality he should commence another series of ten snap-shots, exposing the last of these some few seconds after totality. On developing the plates it was found that everything had gone satisfactorily. The large plates containing the ten snap-shots give the whole story of the chromosphere during twelve seconds, the time to make the ten exposures, and in one of the negatives there are as many as a thousand lines (about).

The last set of ten exposures did not come out quite as expected, for the reason that the duration of totality was a few seconds shorter than had been provided for in the time table, so that only two of the exposures were made before the end of totality. The very last exposure, however, taking about nine seconds after totality, shows many bright lines.

Nine-inch Prismatic Camera.

This instrument was in charge of Dr. W. J. S. Lockyer, who was assisted by Lieut. Percival Jones, R.N.R., and six men. This instrument was also fed by a siderostat, but the tube was not placed horizontally. It was intended with one of the prismatic cameras to so mount the tube that the arcs formed on the photographic plate should be symmetrical about the direction of dispersion, and it was decided that the 9-inch camera should adopt this plan of mounting.

The exact position of the tube to obtain this result was carefully determined by calculation. To facilitate the erection of the instrument at the station two wooden tops to carry the tube were previously made and taken out.

It is satisfactory to state that the photographs showed that the experiment was very successful, the arcs coming out exactly as forecasted.

Although this instrument was capable of only giving about half the dispersion of the 6-inch, the optical parts were better adapted for recording the ultra-violet region of the spectrum.

The programme adopted was similar to that of the 6-inch, there being two large plates ($16 \times 6\frac{1}{2}$) for recording a series of ten snapshots at and near the times of second and third contacts and nine smaller plates for exposure during totality. All the exposures were successfully made, but the lines in the spectrum are not so distinct owing to warping of the wooden tube by the heat and the consequent disturbance of the focus.

I shall refer to the results obtained by the prismatic cameras later in this preliminary report.

Integrating Spectroscope.

This instrument consisted of a large collimator, two prisms of 60°, and a receiving camera. It was entrusted to the care of Lieut. G. C. Quayle, R.N., with two assistants. The light which fed this instrument was obtained from a cœlostat, and there was still sufficient room for another instrument to be utilised, so the coronagraph was set up in the same hut. Although three exposures were made, no results were secured owing, it is feared, to an alteration of the slit, which was found closed after the eclipse.

Six-inch Equatorial with Grating Spectroscope.

This instrument consisted of a 6-inch lens mounted equatorially. The small grating employed contained 17,296 lines to the inch, and in the focus of the eyepiece was placed a small photographic spectrum of iron for comparison.

Professor Pedler, who came to take charge of this instrument was assisted by Mr. Steele, R.N., gunner, and three other volunteers. Up to the present time I have not received Professor Pedler's report of his observations, but I may say that among his observations reported at the time, he recorded the presence of arc lines of iron in the lower corona and the absence of the enhanced lines.

The Coronagraph.

All the more important instruments available for the expedition being employed in the spectroscopic work I could only use a small one for taking photographs of the corona, which were essential for me in order to make comparisons with the chromosphere and coronal rings we hoped to get in the prismatic cameras. The instrument employed, of $4\frac{5}{8}$-inch aperture, was entrusted to Staff-Engineer At Kerr, R.N., who was assisted by three volunteers.

Five photographs were taken. These on development were found to be exceedingly good, the long exposed plate showing a great amount of detail both in the polar rifts and in the streamers.

There being still a small amount of available surface of the cœlostat for other purposes, this was utilised for the 10 × 8 landscape camera which was operated by Mr. Turner. Two exposures were made during totality, with very successful results. The longest exposure shows very well the general form of the corona and the relative lengths of the extensions, the longest streamer being nearly three lunar diameters.

Discs.

The discs, six in number, were put into position by Lieutenant G. C. Quayle, R.N., and Lieutenant C. E. B. Colbeck, R.N., being ranged along the southern wall of the fort, close to the Eclipse Camp. The great altitude (53°) of the sun rendered the operation of setting them up somewhat difficult. Their sizes varied from six to two inches, and they were so placed that they cut off 3, 5, and 7 minutes of arc round the dark moon.

Each disc occupied the time of three men, so that in all eighteen volunteers were employed. Of each party of three, one volunteer kept the eye end in adjustment up to the time of totality, another who was blindfolded ten minutes before totality acted as observer, and the third wrote down the remarks of the observer.

A preliminary examination of the drawings shows that no equatorial extension was observed.

The $3\frac{3}{4}$-inch Equatorial Telescope.

This telescope was used by me to observe the exact time of second and third contacts to give the signals "go" and "over" to the time-keepers. For the first fifty seconds of totality I employed this instrument myself to minutely observe the structure of the rifts and streamers. In my absence it was used by Assistant Engineer H. H. Willmore for the examination of the structure of the corona.

Observations of Stars during Eclipse.

This party of six volunteers was in charge of Lieutenant Henry Blackett, R.N. Each observer was supplied with a photograph of a small star chart of the region near the sun, prepared by Dr. Lockyer. This was afterwards supplemented by another on a larger scale photographed at the office of the Trigonometrical Branch of the Survey of India at Dehra.

Two striking observations were made by most of the observers. First, more stars were seen just before the commencement of totality than during the actual period of totality; that is, they were logged as disappearing just before the total eclipse phase commenced. A similar observation was made by Admiral Don Ulloa in the eclipse of 1778.* Secondly: two observers noted on the chart a bright body, certainly not a star, midway between the planets Mars and Venus. It was seen only for a short time, and that before totality, being estimated as of the Second Magnitude.

Meteorological Observations.

Mr. Eliot, the Meteorological Reporter to the Government of India, brought with him several important instruments with a view of making observations similar to those he had arranged along the whole line of totality. The report of his observations I have not yet received. He was assisted by twelve volunteers.

Observations of Shadow Bands.

Staff-Surgeon Nolan, R.N., observed these phenomena with the help of two assistants. Previous to the eclipse a large white tablecloth was spread on a flat piece of ground in front of two walls intersecting at an angle of 115°, which were whitewashed. The bands were well seen before the second and after the third contact. None were seen during totality. Their direction of travelling was before totality towards the west (N. 88° W.), veering gradually round to S. 60° W. After totality they practically reversed their direction, travelling N. 60° E. They moved too quickly for their rate of motion to be determined, but it was noted that their rate of motion was not constant.

They were estimated to be about $\frac{1}{2}$ to $1\frac{1}{2}$ inches in breadth, but this also varied. The interspaces were gauged at 4 to 6 inches in breadth.

Each observer noted, one minute after totality, a long intermittency during which a large band, about 2 inches broad, passed by itself in a most striking manner.

* 'Phil. Trans.,' 1779, p. 105.

The Chief Results bearing on Solar Theory.

1. *The Spectrum of the Chromosphere.*

Considerable time must elapse before the complete discussion of the numerous photographs taken in the prismatic cameras can be completed. I therefore give here only some general results which can be gathered by a preliminary inspection of them.

I first deal with the determination of the heights of the various absorbing vapours so far as they can be gathered from the photographs, which, of course, only record for us the brightest lower portions of the different arcs, and not their complete extension.

The following table shows the results obtained in the case of some of the most typical lines:—

Lines.	Length of arcs.	Height.	
		In miles.	In secs. of arc.
Ca(K)	130°	6000	13·3
Hydrogen	112°	4500	10·0
He 4471·25	105°	4000	8·9
He 4026·3; Sr 4077·9, 4215·66	86°	2700	6·0
Ca 4226·9; Unknown, 4247	72½°	2000	4·4
Mg ultra-violet triplet			
Fe triplet (4045)	60°	1450	3·2
Strongest arc lines (4307·96, 4325·92, &c.)			
Al 3944·16 and 3961·67			
Fe enhanced lines 4584, 4233	51°	1100	2·4
Mn quartet (4030·9, &c.)			
Fe enhanced quartet (4523·0, &c.) and many other lines	40°	650	1·4
Carbon fluting and many lines, including arc lines of iron	35°	475	1·05

A very noticeable feature of the chromospheric spectra, which the photographs enable us to investigate at different elevations, is the difference in the behaviour of the gaseous and metallic lines. In the spectrum taken very near the moment of second contact, representing that of the lower strata with the spectra of higher ones superposed, the metallic arcs are relatively short and very bright, while in later photographs, representing the spectra of successively higher strata free from admixture with lower ones, the metallic arcs are relatively feeble. This is also indicated in another way by the varying effects seen over the tops of lunar mountains and through indentations in the moon's limb.

Some of the lines are seen to be relatively much brighter in the

upper strata than in the lower, such lines showing no notable increase of brightness at the points where lower strata are revealed through lunar valleys. Chief among these lines are those of hydrogen, helium, and calcium (H and K), but there is an additional line at wave-length 4686·2 or thereabouts, which behaves in the same way.

This line does not appear in Young's list of chromospheric lines, and all attempts to trace it in known spectra have failed. A line apparently coincident with it, however, has been found in the photographed spectrum of a tube containing helium, which is one of a series of comparison spectra being taken with the 6-inch prismatic camera to facilitate the reduction of the eclipse photographs.

The only recognised impurity in the vacuum tube used is oxygen, but besides the line to which reference has been made, there are a few faint lines for which no origins can at present be assigned.

It is worthy of remark that this line falls very near to the first line of the principal series in the spectrum of hydrogen, recently calculated by Rydberg to have a wave-length of 4687·88.*

As in the case of the photographs taken with the prismatic cameras in 1893 and 1896, the spectrum of the chromosphere in 1898 is very different from the Fraunhofer spectrum, so that we have not to deal with a mere reversal of the dark lines of ordinary sunlight into bright ones. (See fig. 1, next page.)

Many very strong chromospheric lines, as the helium lines for example, are not represented among the Fraunhofer lines, while many Fraunhöfer lines are absent from the chromospheric spectrum.

2. *The Spectrum of the Corona.*

The heights of the chief coronal rings as photographed are roughly as follows:—

1474 K	60,000 miles (in lower parts of inner corona).
3987·4	20,000 miles.
4231 ·3	More than 10,000 miles.

The coronal rings not only differ from the chromospheric ones in regard to the heights to which they extend above the photosphere, but also in appearance.

The outlines of these rings are distinctly not connected with the configuration of the chromosphere and prominences. In photographs taken near the beginning and end of totality, the 1474 ring is brightest on the same side of the moon, although the chromosphere and prominences are first visible on one side and then on the other. None of the rings give any indications of increased brightness at the places occupied by prominences. The green ring, corresponding to

* 'Astro. Phys. Jour.,' vol. 6, p. 237.

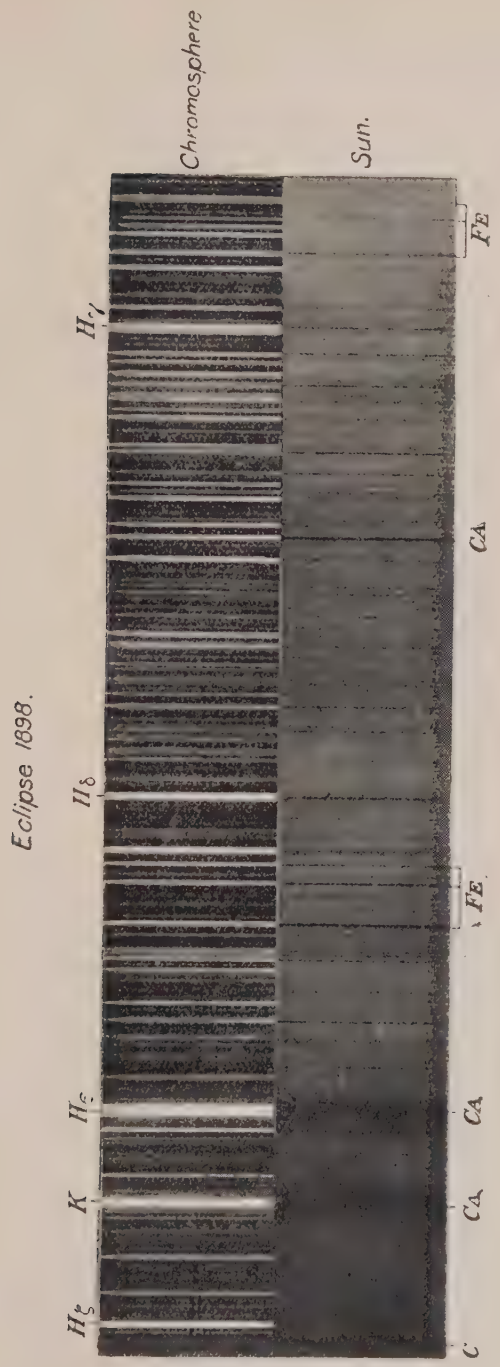


FIG. 1.—Spectrum of Chromosphere as photographed during Eclipse compared with Fraunhöfer lines.

1474 K, which is the brightest of the rings seen, can be traced completely round the limb, and while in some parts it is very feeble, in others it is bright enough to show the brightest projections of the inner corona as photographed with short exposures with the coronagraph. The other rings at 3987 and 4231 can also be traced completely round the limb, but they are fainter on the average and of much more uniform intensity than 1474 K. This latter fact suggests that the additional rings are produced by a substance which is not the same as that to which 1474 K corresponds.

It is interesting to note that the three rings photographed in 1898 were also the most conspicuous in the coronas of 1893 and 1896 as determined by the use of prismatic cameras. The following table gives a comparison of the results obtained in the three eclipses, the wave-lengths for 1898 of course being only provisional.

1893.	1896.	1898.
3987	3988	3987·4
4086	4084	
4217		
4231	4232·0	4231·3
4240		
4280		
4486		
5316·9	5316·9	5316·9

3. *Results regarding the Corona.*

I looked forward to the corona this year with the greatest interest on account of the high temperature of the sun as judged by the fact that scarcely any iron lines have been recorded as most widened in the spectrum of sun spots since the end of 1892; that is, chemically, the maximum sun-spot conditions have been retained since 1893. Hence I was not astonished to see several large spots on the sun on the days preceding the eclipse.

I pointed out in 1878, a year of minimum, that the corona of that year was vastly different from that of 1871, a year of maximum; not only was it very much dimmer, but its spectrum was continuous; there were practically no bright lines, while long equatorial extensions were seen.

Normally we should have expected an approach to the 1878 conditions this year. But both the photographs and eye observations show that the only minimum appearance noticeable was the exquisite tracery near the sun's poles.

The violent magnetic storm and bright aurora on March 15 and 16,

to which Mr. Chree has recently called attention, follow suit with the chemical and eclipse observations, and it is important to note, as Dr. Chree has informed me in a later communication, that there were less violent disturbances on January 15—18 and February 11—16, so that there have been three disturbances separated roughly by an interval of twenty-eight days.

Conclusion.

The extraordinary interest and the skill displayed by the officers and men of H.M.S. "Volage" under Captain King Hall in 1896, and of H.M.S. "Melpomene" under Captain Chisholm Batten in the present year, prove beyond all question that in eclipses in which a man-of-war can be employed the most effective and the most economical means of securing observations is to depend upon the naval personnel, one or two skilled observers being sent out to help in the final adjustments of instruments according to the number it is intended to employ.

At Viziadrug, Mr. Fowler and Dr. Lockyer were enabled to report all the fixed instruments and huts, eight in number, erected and all but the final adjustments made after six days' work, a long break being necessary in the middle of the day in consequence of the heat. Such an achievement as this is beyond all eclipse precedent and was only rendered possible by the help of a large staff of highly trained men. Of the 150 engaged in the operations only three originally formed the expedition.

It is, therefore, quite inappropriate that I, on the part of the expedition, should here tender thanks to Captain Batten, the officers and men of H.M.S. "Melpomene" for their assistance, for as matters turned out we assisted them; but we are anxious to place on record the kindness we received from them both afloat and ashore, and since the great success of the recent observations is due almost entirely to Captain Chisholm Batten and the ship's company of the "Melpomene," I trust that the President and Council of the Royal Society may be pleased to communicate this fact to the Lords Commissioners of the Admiralty.

Among those to whom thanks are specially due are the following representing the Indian Government:—

E. Giles, Esq., Director of Public Instruction, in charge of arrangements made by Bombay Government.
K. R. Bomanji, Esq., Collector of Ratnagiri.
J. L. Jenkins, Esq., Collector of Salt.
E. H. Aitken, Esq., Assistant Collector of Salt.
F. R. Bader, Esq., Assistant Engineer, P.W.D.

Gangadhar Anant Bhat, Executive Engineer, P.W.D.
Govind Goshi, Overseer, P.W.D.
Sadashi Govind Joshi, Clerk to the Overseer, P.W.D.

Thanks are also due to the Officers of the Police, Telegraph, and Customs Departments, and others representing the Bombay Government, for their unceasing efforts to help us in every way.

Everybody was struck by the admirable and smart manner in which the subordinates of the Public Works Department accomplished their respective tasks.

I took upon myself when leaving Viziadrug, to write an unofficial letter to Mr. Bomanji, thanking him, in the name of the expedition, for his great personal kindnesses to us as well as for the valuable assistance we had received from him and the other local representatives of the Government.

L. Lee, Esq., Collector of Customs for Ceylon, and other Customs officials at Colombo rendered valuable assistance to the expedition by granting special facilities and providing means for transhipping the instruments.

The Orient Steam Navigation Company very kindly conveyed the instruments free of charge to and from Colombo.

To W. H. Sinclair, Esq., a former Collector of the district (now retired), I was indebted for the supply of much valuable local information before leaving England.

My own personal thanks are due to Mr. Fowler and Dr. Lockyer, who assisted me in the preliminary work of organisation, and who, while at Viziadrug, worked hard both day and night to further the objects of the expedition; and also to Mr. Bourne, Midshipman, attached to me as Aide-de-camp, who was indefatigable in helping me to carry out the various details of the local organisation.

"Total Solar Eclipse of 1898, January 22. Preliminary Report on the Observations made at Pulgaon, India." By Captain E. H. Hills, R.E., and H. F. Newall, Sec. R.A.S. Received May 25, 1898.

(Plates 9, 10.)

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I. *Origin of the Expedition and General Preparations.*

By Captain Hills and H. F. Newall.

This expedition was one of those organised by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee.

The observers are indebted to the Great Indian Peninsular Railway Company for the carriage of the instruments at reduced rates between Bombay and Pulgaon, and for a considerable reduction of fares to the observers for this journey.

Observers.—The party consisted of :—

Captain E. H. Hills, R.E., Instructor in Chemistry and Photography at the School of Military Engineering, Chatham.
H. F. Newall, Sec. R.A.S., Cambridge Observatory.

(In what follows these will be designated by the initials H. and N.)

It had originally been arranged that Dr. E. J. Stone, Radcliffe Observer, Oxford, should be a member of the party. The vacancy caused by his lamented death was not filled, as it was decided to use the skilled assistance which could be obtained locally in order to carry out part of the programme of work that Dr. Stone intended to attempt, namely the obtaining of twelve photographs of the corona with the double tube camera.

Local Arrangements.—When the preparations were being made for this expedition the Surveyor-General of India intimated that his department would be willing to give what assistance they could. This generous offer was gladly accepted by the Joint Permanent

Eclipse Committee, and the Surveyor-General was asked if he could send—

(*a*) An officer who would take general charge of the camp.
(*b*) Six skilled native assistants.
(*c*) A photographer who would bring with him a suitable dark room ready for erection, and photographic materials.

The officer detailed to take charge of the camp at Pulgaon was Captain G. P. Lenox Conyngham, R.E., and the observers feel that they owe much of the success of the expedition to the excellence of all the arrangements made by him.

The thanks of the observers are also due to Lieut.-Colonel St. G. Gore, R.E., Superintendent of the Trigonometrical Survey, for the continuous interest he took in the work, and to Lieut. G. A. Beazeley, R.E., for much help in the observations, and in the developing and copying of the photographic plates.

The observers are also indebted to the local authorities for their kindness in doing everything that was possible to render the time spent in the Eclipse Camp, both pleasant and profitable, in particular to W. A. Nedham, Esq., Commissioner, Nagpur; S. N. Chitnavis, Esq., Deputy Commissioner, Wardha; and A. C. Blennerhassett, Esq., I.C.S., Assistant Commissioner, Wardha. A number of others, whose names are mentioned below, took part in the actual observations, and the observers wish to express their grateful thanks for the valuable assistance thus rendered.

Selection of Station.—In order that the masonry piers to carry the instruments might be built, and that all the arrangements for forming the camp might be proceeded with before the arrival of the observers it was considered advisable that the choice of the actual station, the approximate position of which had been already decided upon, should be left to the Survey officer in charge. The place selected was Pulgaon, on the Nagpur branch of the Great Indian Peninsular Railway, and the camp and observatory were placed on an open piece of ground about a mile to the north of the station. The position proved excellent in every way.

Arrival at Station.—N. arrived at the camp on January 10, H. on January 12. All the instruments, which had been forwarded direct from Bombay, had previously arrived, and the necessary piers and huts for the observatory were found completed in accordance with the plans prepared and sent by the observers to Captain Lenox Conyngham. It was thus possible at once to proceed with the erection and adjustment of the instruments.

Meteorological Observations.—A continuous set of meteorological observations were made from January 16 to January 23, of which it may be interesting to give a summary.

	Wind.	Barometer.			Temperature in shade.								Maximum in sun.	Minimum on grass.
					Dry bulb.			Wet bulb.			Max.	Min.		
		9 A.M.	12 NOON.	3 P.M.	9 A.M.	12 NOON.	3 P.M.	9 A.M.	12 NOON.	3 P.M.				
Jan. 16	Very light, N. to N.W. ..	29·2	29·4	29·2	66	90	88	58	72	67	95	44	110	42
,, 17	Very light, E. to N.	29·2	29·3	29·2	68	87	89	58	69	69	95	43	110	39
,, 18	Calm	29·2	29·4	29·3	65	86	92	56	69	73	93	41	109	37
,, 19	Calm	29·3	29·4	29·3	68	83	86	58	66	66	89	49	105	36
,, 20	Calm to very light, S.E...	29·2	29·3	29·2	64	82	86	55	65	69	90	43	106	39
,, 21	Calm to light, S.E.	29·2	29·3	29·2	65	86	90	57	69	71	94	46	110	42
,, 22	Calm	29·2	*	29·2	69	90	88	59	73	71	92	45	107	41
,, 23	Calm	29·3	29·3	29·3	70	86	93	62	67	74	96	48	113	43

* Eclipse day. Barometer not read at noon.

Total rainfall, nil. Total cloud amount, nil.

The instruments employed were standard ones by Negretti and Zambra.

It is interesting to compare these figures with those given by Mr. Eliot in his meteorological note prepared in connection with the eclipse. No data are given for Pulgaon, but the conditions are practically the same as those found at the two nearest stations for which the figures are given, namely Akola and Nagpur.

We have then—

	Temperature.			Cloud amount (parts in 10).		Rainfall.
	Max.	Min.	Daily range.	10 A.M.	4 P.M.	
Average at end of January in a few recent years—						in.
Akola	84	53	31	1·00	1·48	0·11
Nagpur	83	55	28	1·41	2·18	0·14
Observed—Pulgaon	93	44	49	Nil	Nil	Nil

The figures exhibit the futility of selecting an eclipse station on meteorological data only.

Departure.—The observers left the camp on January 25.

II. *Totality at Pulgaon.*

By Captain Hills and H. F. Newall.

The preparations for totality as regards the instruction and drilling of the assistants calls for little mention. The skilled native assistants, provided by the kindness of the Surveyor-General, were thoroughly accustomed to observing work, and the preparations and preliminary drills proceeded with the utmost smoothness.

The two men selected as timekeepers were instructed to call out the seconds from the beats of a metronome, which had been previously carefully rated.

The signal for the beginning of totality was given by Captain Lenox Conyngham who was making the exposures with the double tube camera, but it was also necessary for the spectroscopic work to get a signal at some definite time before totality which was accomplished by the following method :—

The length of the diminishing crescent of the sun was calculated for 15 seconds before totality. The observer in charge of the double tube camera watched the image on his ground glass and gave a signal when the crescent had arrived at the calculated length. The actual interval between the 15 second signal and the beginning of totality was 13 seconds.

Observing Party.—The following is a complete list of the whole observing party :—

Double Tube Camera.

In charge of instrument—Captain G. P. Lenox Conyngham, R.E.
Exposer—Babu S. C. Goha.
Recorder—Babu S. N. Saha.
Handing slides—Kali Din.
Receiving ditto—Mahabri.
Holding bags—Balgar.

Spectroscopic Cameras.

Observer—Captain E. H. Hills, R.E.
Exposer—Quartz spectroscope, Lieutenant F. R. H. Eustace, R.E.
,, —Flint spectroscope, Babu I. C. Dev.
Assistant in charge of slow motion—Lieutenant G. A. Beazeley, R.E.
Recorder—Mrs. Hills.

Spectroscope with Two Slits.

Observer—Mr. H. F. Newall.
Assistants—Mrs. Newall, Babu S. B. Shome.

Grating Spectroscope.

Observer—Mr. H. F. Newall.
Assistant—Mr. A. C. Blennerhassett, I.C.S.

Time Keepers.

Sub-Assistant Superintendent Hanuman Prasad.
Babu Lal Singh.

Recording Thermometers.

Captain G. C. Kemp, R.E.

Observing Magnetometer.

Lieut.-Colonel St. G. Gore, R.E.

Photographing Shadow Bands.

Mr. J. Harrold.

Recording Contacts.

1st and 4th—Captain Hills, R.E.
2nd—Captain G. P. Lenox Conyngham, R.E.
3rd—Mr. E. Batchelor, I.C.S.

Observed Times of Contacts.

Pulgaon—Latitude, 20° 44′ 10″·6 N.
Longitude, 78° 19′ 2″·5 E.

Computed distance from centre line, 4 miles.

The observed local mean times of contacts were :—

1st.....	11 hrs.	50 min.	43·0 secs.	
2nd	13 ,,	21 ,,	3·0 ,,	
3rd	13 ,,	22 ,,	58·0 ,,	
4th	14 ,,	43 ,,	54·5 ,,	

The chronometer employed was rated by theodolite observations, and was probably correct within 1 sec.

Temperature Observations.—The result of the observations made for the two hours about totality were as follows :—

L.M.T.	In sun.		In shade.		
	Black bulb.	Glass bulb.	Dry bulb.	Wet bulb.	
h. m.					
12 21	99	93	90	73	
12 36	94	93	87	70	
12 51	90	99	85	69	
13 6	84	84	83	67	
13 21	79	78	80	66	Commencement of totality.
13 23	77	77	79	66	End of totality.
13 31	75	74	78	66	Lowest readings.
13 46	81	82	78	67	
14 1	89	86	82	67	
14 16	93	90	85	68	
14 31	97	94	86	69	

Magnetometer.—Colonel Gore made observations with the magnetometer with a view of detecting variation in the horizontal component of the earth's magnetic field during the eclipse. No change was observed.

Shadow Bands.—An attempt was made to photograph these with a small camera provided with an excellent Cooke lens of large aperture (F/6·3). A white sheet was stretched opposite to the sun's position, and a series of exposures was made at beginning and end of totality. Several spectators saw shadow bands, but no trace is discoverable on the photographs.

III.—*The Double-tube Camera.*

By Capt. Hills.

Instrument.—This camera was the one used by Mr. Taylor in Brazil in 1893, and was taken to Norway by Dr. Common in 1896. The tube is of wood, 6 feet long, and 14 × 7 inches in section, divided

by a partition into two square tubes of 7 × 7-inch section. In one of these was placed the "Abney" lens of 4 inches aperture and 5 feet 2 inches focal length, giving an image of the sun 0·57 inch in diameter; in the other the photoheliograph objective (used in Transit of Venus expedition), of 4 inches aperture and 5 feet focal length, with a Dallmeyer secondary magnifier of $7\frac{1}{2}$ inches focus placed 5 inches within the focus, the combination giving an image of the sun $1\frac{1}{2}$ inches in diameter. The camera was furnished with six plate-holders, each taking two plates of 160 × 160 mm., as in use for the astrographic chart, both plates being exposed by a quarter-turn of one shutter. The camera was pointed to a 16-inch plane mirror, made by Dr. Common, and mounted as a cœlostat by Mr. Hammersley after a design by Dr. Common, the sun's rays being thus reflected into the telescope.

The camera and cœlostat were not placed in a hut, but a screen of bamboo matting was erected round the whole instrument, to protect it from the wind, to which the cœlostat is particularly sensitive. Another portion of bamboo screen was placed horizontally above the camera, to protect the observer and the wooden body of the camera from the direct rays of the sun.

Mounting and Adjustment.—The cœlostat was placed on a masonry pier level with the ground. As some trouble had previously been experienced with the driving clock, owing to the heavy weight necessary, care was taken on this occasion that it should be very rigidly fixed in position. The method adopted was to screw the clock down on to a stout wooden base-board, which in its turn was firmly bolted to the masonry pier carrying the cœlostat, the driving cord being led off horizontally under one pulley attached to the base-board, and over another pulley hanging from the top of a strong wooden trestle about 6 feet high. Railway fishplates were used as weights. With this method no trouble at all was experienced, and the clock-driving was irreproachable.

In order to carry the camera, two parallel brick walls were built on the west side of the cœlostat, and on the top of each of these a 4-feet length of heavy rail was placed, held in ordinary railway chairs, lent for the purpose by the railway authorities at Pulgaon. A wooden stop or button fixed on the under side of the camera rested against the lower rail and prevented the camera from slipping down towards the mirror.

The angle at which the camera was set was so selected that the slide end should be at a suitable height for working. It was found convenient to direct the camera towards a point about 30° below the horizon, a little to the south of east. The focussing was done by reflection, and calls for no special remark, the final adjustment being accomplished by using the cœlostat mirror.

The adjustment of the axis of the cœlostat was effected very quickly by means of the attached declination theodolite. The level attached to the telescope makes it possible to adjust in altitude without any astronomical observation, for the latitude of the place can be taken from the map with sufficient accuracy; and setting the telescope to the south declination equal to the co-latitude, and in the meridian, the level should indicate horizontality. Index errors of the circle and level are eliminated by reversal of the instrument. There is a slight uncertainty attending the placing of the telescope in the meridian, but this does not seriously affect the adjustment in altitude. If a cross-level were made for the pivots of the telescope, this uncertainty could be removed.

To adjust in azimuth we must have an observation of the sun (or a star) at a distance from the meridian. Observing his declination (in reversed positions of the instrument and taking the mean), the instrument must be moved in azimuth until this observed declination agrees with that given in the 'Nautical Almanac.' A very few trials, if the sun can be seen for half an hour, will soon indicate the true azimuth without any calculations, within a minute or two of arc, though if the instrument be moved much in azimuth the altitude observation must be repeated.

After the initial adjustment of the cœlostat it was not disturbed, but the adjustment was re-tested at intervals, with the following results. The individual readings were only taken to minutes of arc, but both limbs of the sun were observed in both positions of the instrument, and the mean of the four set down:—

	Cœlostat.	Observer H.		
Date.	Hour angle of sun. hrs.	Observed decl.	Tabular decl.	O.—C.
Jan. 15.....	−3·0	21° 7′	21° 7′	0′
16.....	−3·0	20 55	20 56	−1
17.....	+2·0	20 40	20 42	−2
19.....	−2·5	20 18	20 20	−2
20.....	+3·0	20 6	20 7	−1

From this general watch kept on the instrument it is clear that the adjustments remained good within 1′ or 2′, which is more than sufficient for the purpose. The only other adjustment required is the setting of the face of the mirror parallel to the polar axis of the instrument. This was easily effected by reversing the mirror in the Ys and observing if the sun's image in the two cases crossed the same position on the ground glass when the mirror was moved in right ascension.

Three screws are provided in the base of the mirror cell for correcting this error should any be found.

Programme of Observations.—The six slides were filled and intended to be exposed as follows:—

No. of slide.	Exposure.	Plate.
1	2 secs.	Ilford "Empress."
2	8 ,,	Ditto, ditto.
3	12 ,,	Ditto, Special Rapid.
4	24 ,,	Ditto, ditto.
5	12 ,,	Ditto, "Empress."
6	4 ,,	Ditto, ditto.

Plates 2, 3, 4, 5 were backed with a solution of asphalte in benzol and had the Abney standard squares impressed on them. If the rapidity of the Special Rapid be taken as twice that of the Empress plates, the above programme gives a series of equivalent exposures of

2, 4, 8, 12, 24, 48 seconds.

No exposures of less than 2 seconds were made, because it was considered that the detail of the inner corona would be better shown by the large scale pictures, of which at least four separate sets were being taken by independent observers at other stations.

The orientation of the corona was determined by the following method: After the last exposure had been completed the clock was stopped and the whole instrument was left untouched, with the slide still in the camera, till night. The Abney lens was then uncovered for about $2\frac{3}{4}$ hours, the mirror being left stationary, and a series of star trails were thereby drawn across the plate.

A recorder was employed whose duty was to note the exact time of each exposure made during the eclipse. They were as follows:—

Slide No.	Exposure according to programme.	Actual exposure.		
		Shutter opened.	Shutter closed.	Duration.
		Beginning of totality = zero.		
	secs.	min. sec.	min. sec.	sec.
1	2	0 5·0	0 7·5	2·5
2	8	0 14·0	0 22·0	8·0
3	12	0 27·5	0 39·0	11·5
4	24	0 47·0	1 11·0	24·0
5	12	1 18·5	1 30·5	12·0
6	4	1 37·0	1 41·0	4·0

All the above plates were successfully developed the night after the eclipse, and positive copies on glass were made to guard against loss.

A reproduction of one of the best photographs (No. 3, Dallmeyer lens, 12 secs. exposure), is given in Plate 1 (frontispiece).

IV.—*The Spectroscopic Cameras.*

By Capt. Hills.

Instruments.—The details of the two spectroscopes used were as follows:—

	Spectroscope No. 1.	Spectroscope No. 2.
Objective	Cooke achromatic, 4½ in. aperture, 5 ft. 10 in. focus.	Single quartz lens, 5 in. aperture, 4 ft. 9 in. focus.
Collimator and camera lenses.	Single quartz lens; 2½ in. aperture, 30 in. focus.	Single quartz lens, 3 in. aperture, 36 in. focus.
Slit	1½ in. by 0·0018 in.	2 in. by 0·0014 in.
Prisms	Two dense flint prisms of 60°, 4½ in. base, 2½ in. height.	Four double quartz prisms of 60° (each prism being composed of two half-prisms of right- and left-handed quartz), 3½ in. base, 2¾ in. height.
Prisms at min. deviation for	H_γ.	H_ϵ.
Position of slit with respect to sun's image.	Parallel to meridian through sun's centre, cutting limb at point of second contact.	Vertically diametral.

The slits were in each case adjusted to such a width as to realise one-seventh of the theoretical maximum resolving power of the prisms. In the case of spectroscope No. 1 which, as will be shortly seen, was used for most of the work, this amounted to about 0·3 of an Angström unit in the violet. It may be noted that any higher degree of resolving power would have been wasted owing to the coarseness of grain of the photographic plate, the above figure representing not only the calculated resolving power of the instrument, but that actually realised on a trial plate.

The length of the spectrum on the plate was 3¼ inches from H_β to K.

Both spectroscopes were mounted in an approximately horizontal position, and were supplied with light by a heliostat, furnished with a 12-inch flat mirror.

Erection and adjustment of Instrument.—The heliostat and spectroscopes were placed on masonry piers, and a hut of bamboo matting was built up round the latter. The heliostat was left in the open, and, such was the dryness of the air, that it was found that a sheet tied over it at night was more than sufficient to protect it from any damp.

The adjustment of the polar axis of the heliostat was carried out by means of an attached theodolite in precisely the same manner as has been described above in the case of the cœlostat. As it was not possible to reverse the instrument when the slow motion in right ascension was attached, the position of the axis when once adjusted was not retested. This, however, was of little importance, as great accuracy in the driving is not required for this work.

The adjustments of the spectroscopes call for no special mention.

Programme of Exposures.—Two separate lines of work were undertaken :—

(1) The recording of the spectrum of the corona—using for this purpose both spectroscopes, and giving only one exposure of as long a duration as possible.

(2) The recording of the "flash" or spectrum of the sun's limb at both the beginning and end of totality.

For this purpose, spectroscope No. 1 only was used, the camera being provided with a sliding plate, by which means a large number of successive exposures could be made at short intervals.

It was intended to begin the exposures about 10 seconds before second contact, and to continue them till 7 seconds after it, and to expose a similar series at third contact.

In order to get the latter series, it was necessary to shift the image on the slit, which was done by the slow motion of the heliostat, an assistant being stationed at the latter, watching the sun through the theodolite telescope attached to the polar axis.

All the available time during totality, was employed in the long exposure for the corona spectrum.

The complete programme of exposures as drawn up, was as follows, the expected duration of totality being 115 seconds :—

Spectroscope.	No. of slide.	Exposures.	Time in totality.	Plate.
No. 1...	1	10 of 1 sec.	−10 to +7 secs.	Lumière "green sensitive."
	2	1 of 85 secs.	15 to 100 secs.	,, ,, ,,
	3	10 of 1 sec.	108 to 125 secs.	,, ,, ,,
No. 2...	1	1 of 98 secs.	7 to 105 secs.	Ilford Special Rapid.

All the essential points of this programme were carried out The actual time of each exposure was as accurately as can be ascertained,

2nd contact: −10, −8, −6, −4, −2, 0, +2, +4, +6, +8, seconds.
3rd „ −3, −1, +1, +3, +5, +8, +10, seconds.
Corona: Spectroscope No. 1. Exposed 79 seconds from 21—100.
„ „ No. 2. „ 98 „ „ 7—105.

The second series did not begin quite as soon as had been intended, and between the fifth and sixth exposures there was rather a longer interval than between the others, owing to a slight mistake on the part of the exposer. This is, however, of no consequence, as all the interest centres about the photographs taken within 5 seconds of the contact.

The Corona Spectrum.—A reproduction of the corona spectrum as obtained by the two-prism flint spectroscope is given in Plate 2. It is obvious that the photographic intensity of the continuous spectrum fell off very rapidly on receding from the limb. No trace of it is seen at a greater distance than 4′.

Five strong bright lines of unquestionably coronal origin are to be seen. Their wave-lengths, and relative intensities may be provisionally given as—

λ (Rowland).	Photographic intensity.
3987·0	5
4233·5	10
4360·0	3
4567·9	8
5316·9	8

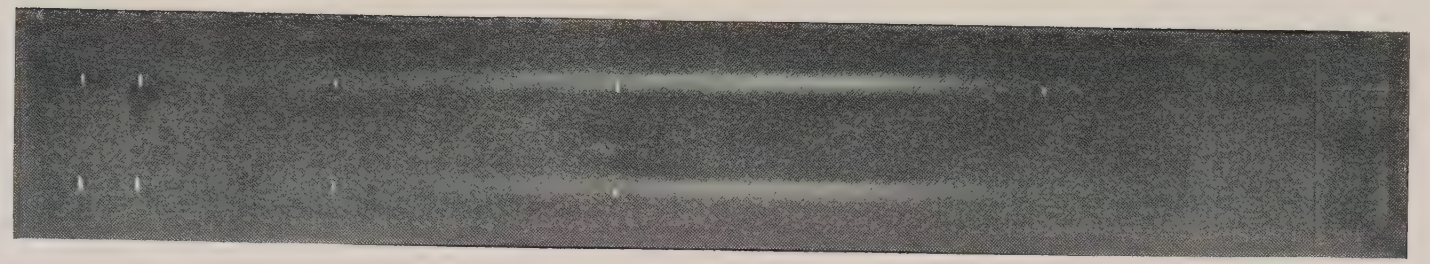
There are other fainter lines whose wave-lengths have not yet been determined.

Spectroscope No. 2, with the quartz train, gave a corona spectrum stretching a considerable distance into the ultra-violet, but of feeble intensity. A strong bright line occurs at λ 3801·0, and the lines given above are also to be plainly seen with the exception of the well known line in the green which was outside the plate.

Spectrum of the limb.—The two series of spectra of the limb contain an immense amount of detail, and will take a considerable time for complete examination. As an indication of the character of the results obtained, reproductions of portions of the two spectra taken at second and third contacts are given in Plate 3.

As considerable interest attaches to the question of the connection between the bright line spectrum of the limb and the solar spectrum, a reproduction of the latter, taken with the same instrument is appended.

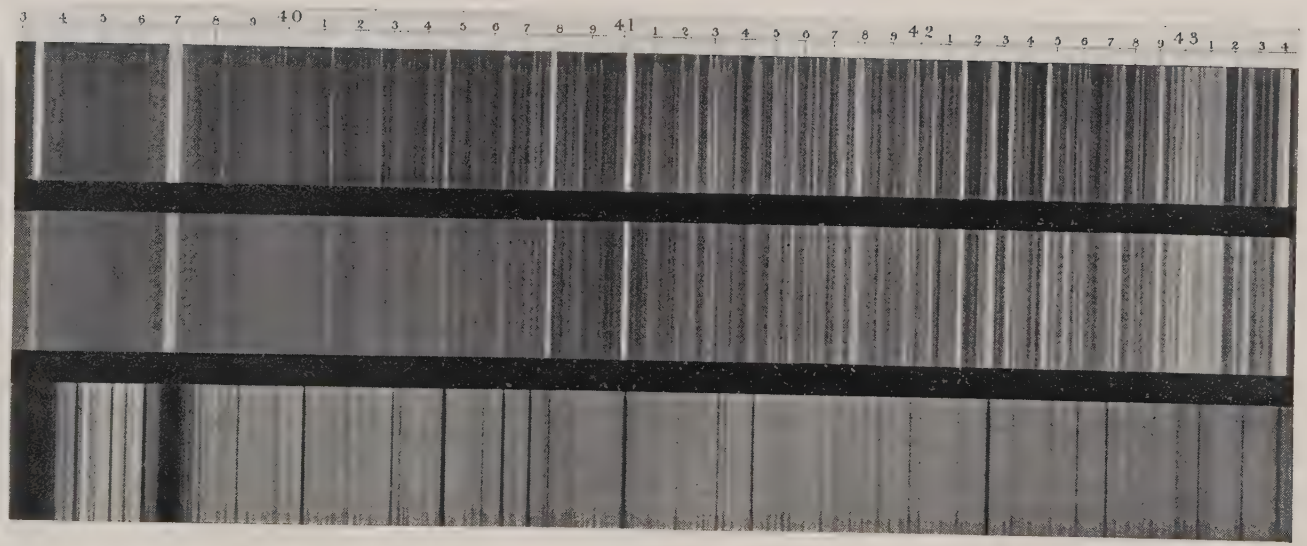
CORONA SPECTRUM.



From photograph taken with a 2-prism flint spectroscope, at Pulgaon, by Captain E. H. Hills, R.E. Enlarged 1½ times.

Spectrum of Sun's Limb.

(Region H_γ to K.)


3 4 5 6 7 8 9 40 1 2 3 4 5 6 7 8 9 41 1 2 3 4 5 6 7 8 9 42 1 2 3 4 5 6 7 8 9 43 1 2 3 4
Spectra of limb.
At point of 2nd contact.
At point of 3rd contact.
Solar spectrum.

From photographs taken with a 2-prism flint spectroscope, at Pulgaon, by Captain E. H. Hills, R.E. Enlarged $3\frac{1}{2}$ times.

V.—*The Spectroscope with Two Slits.*

By H. F. Newall.

It was intended to attempt (i) to determine by a spectrographic method, the difference in velocity in the line of sight in the eastern and western equatorial regions of the corona, (ii) to utilize the same material, as was obtained for the first research, for a comparison of the spectra of widely separated parts of the corona, and (iii) to use the same instrument in securing photographs of the bright line spectrum of the sun's limb at the end of totality, to be used for the accurate determination of the wave-lengths of the bright lines.

The instrument provided for these purposes is a four-prism spectroscope with two slits.

The train of prisms is of such dimensions and construction, as to transmit a 2-inch beam of light, and to produce a minimum deviation of 180° for H_γ. The collimator and camera are set parallel to one another.

The whole spectroscope is mounted so as to turn about an axis, parallel to the collimator. The axis is rotated (with a period of 24 hours) by clockwork, and is tilted so as to be parallel to the earth's axis. In this position the collimator points to the north pole.

The tube of the collimator is prolonged beyond the plane of the slit, and is arranged to carry at its end a mirror of speculum metal and an object glass, by means of which an image of the sun can be thrown upon the slit.

The whole arrangement thus consists of a spectroscope combined with a polar heliostat, and in virtue of the fact that the spectroscope is rotated together with the mirror, the image of any celestial object thrown upon the slit does not rotate relatively to the slit. Furthermore, the mirror is mounted in such a manner that the axis about which it can be tilted—namely the declination axis—can be oriented relatively to the collimator tube, so that any diameter of the sun may be set parallel to the slit.

The two slits with which the collimator is provided are parallel to one another in the focal plane of the collimator lens, and are separated by such a distance that when the image of the eclipsed sun is thrown between the slits, one is illuminated by the eastern, the other by the western equatorial region of the corona. The top half of one slit is covered, and also the bottom half of the other. The exposures for the two sides of the corona are made simultaneously, and the resulting photograph should give two spectra side by side on the same plate, one slightly displaced, relatively to the other, by an amount depending on the separation of the two slits and the construction and adjustments of the spectroscope.

It was decided that certain coronal lines in the neighbourhood of

λ 4233 would be the best available for the determination of displacement due to velocity.

The linear dispersion in the photographed spectrum is about 15 tenthmetres per millimetre at H_γ. The relation between the velocity in the line of sight and one complete revolution of the micrometer to be used in the measuring the plate is about 260 kilometres per second for one revolution.

The scale of the photograph is such that one degree on the sky corresponds to about 9 mm. on the plate.

The effective aperture of the combination regarded as an instrument for producing monochromatic images of a slit-shaped region of the corona is $\frac{1}{12}$.

The adjustment of the axis of the instrument to parallelism with the earth's axis, was accomplished in the same manner as that adopted for adjusting the cœlostat. A theodolite with declination circle was attached to a part of the frame of the spectroscope, specially prepared for it, between the camera and the collimator. The adjustment was very easily and satisfactorily made: in altitude by observations made with the spirit level attached to the theodolite-telescope, and in azimuth by observations of the sun made some hours before or after noon.

Programme of Exposures and General Results.

I. *Spectra of the Corona.*—A set of five photographs, from which the relative velocity in the line of sight of the eastern and western equatorial regions of the corona could be deduced, was to be taken with the spectroscope with two slits.

The programme of exposures was carried out completely successfully, as follows:—

Thirty minutes before totality, plate A was exposed for 15 seconds for spectra of sunlight diffused from the sky near the sun.

Fifteen minutes before totality, plate B was exposed for 20 seconds for a duplicate of plate A taken in falling temperature.

During totality, plate No. 1 was exposed for 100 seconds for the spectra of the eastern and western regions of the corona.

Fifteen minutes after totality, plate C was exposed for 15 seconds for spectra of sunlight diffused from the sky near the sun.

Thirty minutes after totality, plate D was exposed for 15 seconds for a duplicate of plate C under different temperature conditions.

Result.—On development, the photographic plate No. 1 showed no trace of any impress of the coronal spectra, though the development was pressed as far as possible.

It is clear that the failure is due to the faintness of the corona in the region photographed. Captain Hills was successful in photo-

graphing the spectrum of the corona at the same station, but the radial extension of the bright lines and also of the continuous spectrum is unexpectedly small. In neither of his photographs is the spectrum traceable further than about 4′ from the limb of the sun. N., basing his attempt on the results obtained by Deslandres in 1893 and by Abney and Thorpe, had tried to photograph the spectrum at nearly 8′ from the limb of the sun. The apparatus used on the present occasion was of such design and construction, that it was expected to give considerably brighter images than those used by Deslandres in 1893.

II. *Spectrum of the Sun's Limb.*—With the same spectroscope, photographs were to be taken of the bright line spectrum of the sun's limb at the end of totality.

Ten seconds before the end of totality, the exposure referred to in the preceding paragraph was completed; and whilst another plate-holder was being placed in the camera of the spectroscope, the adjustments in R.A. and Declination were changed so that the image of the chromosphere, which was being disclosed near the point of third contact, was adjusted on one of the two slits. Four exposures were then made in rapid succession.

Results.—The photographs thus obtained, give spectra ranging from about $\lambda 3900$ to $\lambda 4900$; and the first of the series contains a vast number of bright lines, generally similar to those seen in Captain Hills' photographs, and to those shown in the photograph obtained by Mr. Shackleton in Novaya Zemlya, 1896, August 9, and reproduced in Sir Norman Lockyer's Preliminary Report,* and also to those obtained by Mr. Fowler in 1893, and reproduced in Sir Norman Lockyer's Report.†

An additional point of interest in the first photograph of the series is that many absorption lines are also visible. A cursory comparison with the solar spectrum discloses the interesting fact that these lines differ in intensity from the absorption lines in the ordinary solar spectrum.

VI. *The Objective Grating Telescope.*

By H. F. Newall.

An objective grating telescope was used for visual observations of the coronal ring in the green light of wave-length 5316·9 (1474 K).

A plane grating, by Rowland, 14,438 lines to the inch on a ruled surface, $3\frac{1}{2} \times 2\frac{1}{8}$ inches, was fixed on a turn-table in front of a telescope of focal length 29 inches and aperture $3\frac{1}{2}$ inches. A positive eye-piece was used which gave a magnifying power of 19·2, and whose circular field of view was rather more than 1° in diameter.

* 'Phil. Trans.,' A, vol. 189 (1897), pp. 259—263.

† *Ibid.*, A, vol. 187 (1896), Plate 14.

The instrument was mounted so that the telescope was parallel to the earth's axis and pointed towards the north pole. The grating was used in a manner analogous to that in which the mirror of a polar heliostat is used. The light of the corona was incident on the grating at an angle of about 57°, and diffracted beam utilised in the telescope left the grating at an angle of about 13°. In this position of the grating, the green of the second order was used, and the magnifying power of the grating was a little greater than $\frac{1}{2}$, so that the distorted coronal ring was an ellipse, in which the major axis was about twice as great as the minor axis; the minor axis was parallel to the length of the spectrum and perpendicular to the direction of daily motion. No clockwork was used, but a slow motion of a very simple construction was provided and found to work perfectly satisfactorily. The observations were begun 6 seconds after the beginning of totality, and were completed in about 70 seconds.

Results.—The coronal ring was seen in the spectrum of the second order with great distinctness and with such brilliancy as to leave no doubt that it could have been photographed.

None of the fine radial structure of the corona could be seen, though it was especially looked for; but broad patches of light were clearly visible in different positions round the ring.

A drawing of the brighter extensions was made during the eclipse, the observer (N.) keeping himself intentionally in ignorance of the orientation of the image seen in the eye-piece until after the observations were completed so as to avoid bias. A preliminary comparison of the drawing with the direct photographs of the corona has been made, and the following general statements will probably not require much revision on a closer comparison :—

(i) There appeared to be glowing "Coronium" (assuming that the radiation of wave-length 5316·9 is rightly attributed to an element "coronium") at all points round the sun's limb extending radially to distances estimated as ranging between 4′ and 14′.

(ii) The luminosity was not uniform round the limb, but in no position was it entirely absent.

(iii) No *fine* radial streamers comparable with those seen near the poles of the sun in ordinary direct photographs of the corona were observed, though this fine structure was specially looked for.

(iv) In certain positions round the limb patches of increased luminosity were seen; in all, seven patches were noted; in several cases the extension was considerably greater in a radial direction than in a tangential. The bases of the

broad streamers on the limb subtended angles ranging from 10° to 30° at the centre of the sun's disc, and the radial extension in three cases was estimated as being greater than 12′.

(v) Two of the long streamers referred to in the last paragraph were found to coincide roughly in position with marked broad extensions in the direct photographs of the corona, viz., that to the N.E. and that to the S.W. But the third long streamer to the N. seems to have no connection with any obvious extension in the photographs.

(vi) There was no marked "coronium" luminosity corresponding either to the double-rayed extension in the N.W. quadrant or to the broad extension in the S.E. quadrant.

(vii) As far as it has been possible to pursue the investigation at present, there has appeared no relation between the position of the brighter patches of coronium and the prominences, except perhaps near the three prominences in the N.W. quadrant.

VII. *Polariscopic Observations.*

By H. F. Newall.

It was intended to devote any time that remained over, after providing for the three foregoing investigations during the eclipse, to (i) a search for faint extensions of the corona with the aid of a polariscope, or as an alternative (ii) a general investigation of the nature of the polarisation-phenomena visible during an eclipse. It was expected that results obtained in the latter investigation would probably only be serviceable in suggesting methods of research for future eclipses.

The polariscope used consists of a Nicol prism with a Savart plate attached in front of it. The field of view of the instrument is lozenge-shaped after the manner of Nicol prisms, the long axis being 29° long and the short axis 24°. The width of the central band due to the Savart plate was approximately 1° 25′ between the centres of the first lateral dark bands, the centre being regarded as that part of the dark band where the dusky red meets the steel blue. The plate had been adjusted relatively to the Nicol prism, so that the bands when visible were parallel to the principal plane of the Nicol, and they were kept in this relative position throughout the observations. The instrument was used without telescope or circles.

Observations.—When first the instrument was put to the eye, about 85 secs. after the beginning of totality, bands were visible over the whole field of sky seen through the Nicol prism. Not only were the alternations of brightness seen, but the colours of the bands appeared

with unexpected vividness. They were seen at all points within 30° of the sun, with little or no variation in vividness, and as the instrument happened first to be held, the bands were approximately parallel to the sun's axis. These vivid bands are attributed to the polarisation of the light scattered (diffracted) by solid particles in the earth's atmosphere.

The bands were so disconcertingly vivid that a few moments were wasted in inspection of the instrument, but immediately afterwards observations were quietly renewed, the search for faint coronal extensions was abandoned, and attention was confined to the phenomena of polarisation.

The instrument was rotated about its axis, and the bands faded from view and became invisible in a certain position. It was thought immediately after the eclipse that the observations made were enough to prove that the plane of polarisation was neither vertical nor horizontal, but it has since been found that the evidence is not such as to warrant this statement. When the bands had become invisible in the outer part of the field of view, the rotation of the instrument was discontinued for a moment. The eye then gradually became aware of faint colours over the corona, but the distribution appeared to be uneven—rather in patches than in bands. These colours are attributed to the polarisation proper of the corona. The "patchy" distribution is doubtless a result of the nature (presumably radial) of the polarisation of the corona, and of the largeness of the scale of the bands compared with the diameter of the moon (1° 25′ : 33′). The fact that the colours appeared faint in contrast with the vivid sky-bands previously seen may be referred to several alternative explanations which cannot well be dealt with here in detail. It is obvious that the ratio of the brightness of the light scattered by the sky to that of the light of the corona plays as important a part as the proportion of the coronal light that may be regarded as polarised.

Next, attention was directed to the corona near the limb, and the central part of the central band was observed while the instrument was rotated, the central band being kept radial to the sun's disc. The observed central part was seen to be bright at all points round the limb on the east side, whether the central sky-band were bright or dark.

Then the bands were set so that one of the first dark lateral bands was tolerably close to the moon's limb, with its centre perhaps half a moon's diameter from the limb. The band was observed to be bright near the limb, and to be dark at a short distance on either side.

Both of the last mentioned observations point to the idea that the light scattered by the atmosphere was comparable in brightness with the corona at points not far distant from the sun's limb.

The incompleteness of the observations is recognised, but on the whole it would appear that their suggestiveness justified the observer in devoting 15 seconds to making them.

The observed intensity of the bands, attributed to sky polarisation, is evidence of the quantity of light reflected by solid particles in the atmosphere. It seems not improbable that the unexpected brightness of the general sky and landscape during totality may have been connected with the amount of light reflected from the dust suspended in the atmosphere and illuminated by the sun-lit plains outside the moon's shadow. The light colouring of the plains, due to the dried herbage at that time of year, is very marked at Pulgaon, but it must not be forgotten that the "sun-lit plains" were in the moon's penumbral shadow for more than an hour both before and after totality.

The observations occupied the 15 seconds, ending 15 seconds before the end of totality.

About 30 seconds after the end of totality, polarisation was again looked for, but no trace could be detected near the sun in any position of the instrument.

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